MECHANICAL ENGINEERING

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

September 1931

Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 20th and Northampton Streets, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-Ninth Street, New York
(Cable Address, "Dynamic" New York)

Vol. 53 September, 1931 Number 9

CONTENTS OF THIS ISSUE

DEPARTMENTAL

ADVERTISING

Price 60 Cents a Copy, $5.00 a Year; to Members and Affiliates, 50 Cents a Copy, $4.00 a Year. Postage to Canada, 75 Cents Additional, to Foreign Countries, $1.50 Additional. Changes of Address must be received at Society Headquarters two weeks before they are to be effective on our mailing list. Please send old, as well as new, address.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

What It's All About

RECENT DEVELOPMENTS IN ARMY MECHANIZATION have aimed at the greater protection and mobility of men engaged in warfare on land which is provided in the so-called "tank." This essentially mechanical contrivance, based upon the peaceful agricultural tractor, is a distinctly engineering contribution to the art of war and as such is of interest to engineers. In an article written especially for MECHANICAL ENGINEERING and published in the September issue, Capt. John K. Christmas, Ordnance Dept., U. S. A., tells about the mechanization policy of the U. S. War Department and the problems that face designers of automotive equipment for combat purposes.

:: :: ::

THE WEAR OF METALS is one of many subjects of importance to engineers about which little is known. While every one will concede that wear exists, while it is known that some alloys of steel, for instance, withstand wear better than others, little is known about the mechanism of wear and how to test the wear resistance of a metal. In the September issue of MECHANICAL ENGINEERING, Louis Jordan, metallurgist in the Bureau of Standards, offers a preliminary analysis of the problem in which he suggests that wear takes place by abrasion, by erosion, and by galling. After a discussion of the importance of wear in engineering design and service, Mr. Jordan considers methods of protection against wear, and concludes by showing what methods are available for making laboratory measurements of wear resistance.

:: :: ::

THE 1930 EARNINGS OF MECHANICAL ENGINEERS have been investigated by a committee of the A.S.M.E. More than 9000 members of the Society answered a questionnaire that was designed to establish the statistical facts of earnings in such detail that a comprehensive study could be made of them. In a report published in the September issue of MECHANICAL ENGINEERING, comparisons are made on the basis of 1930 earnings of all engineers reporting, and on the median earnings by geographical areas, by type of education, by type of industry, and by type of occupation. The results of the investigation are worthy of close study.

:: :: ::

DISTRIBUTION OF NATURAL GAS IN THE UNITED STATES by long-distance pipe lines is very much in the public mind. Time was when natural gas was available only in restricted districts near producing fields, but a recently constructed line carrying gas from Texas to Chicago has demonstrated that long-distribution has been made feasible because of the introduction of steel pipe. In the September issue of MECHANICAL ENGINEERING, H. R. Moorhouse, industrial economist for Arthur G. McKee & Co., of Cleveland, discusses the history and problems of natural-gas distribution and presents some interesting statistics.

:: :: ::

INCREASING THE DURABILITY OF PLYWOOD increases the adaptability and serviceability of an exceedingly useful material. The factor of durability, of course, is greatly affected by the effectiveness of the preservative treatment for retarding decomposition of the glue used and for protecting the wood against decay. Results of tests on such treatments made at the Forest Products Laboratory of the U. S. Department of Agriculture, Madison, Wis., are reported in the September issue of MECHANICAL ENGINEERING by Don Brouse, assistant engineer at the Laboratory.

:: :: ::

CONTACT STRESSES IN GEARS can be very effectively studied by photoelastic methods. A model of tooth forms made of celluloid, Bakelite, or some material having similar properties, is subjected to polarized light, and under a condition of stress, bands of color in the model indicate visually the distribution of the stresses in the model. In the September issue of MECHANICAL ENGINEERING; R. V. Baud reports further work on the problem of stresses in gears carried on by him and his colleagues at the Westinghouse Research Laboratory, supplementing articles published in the November, 1930, and March, 1931, issues.

:: :: ::

PRODUCT DESIGN for increased utility and improved marketability is engaging the attention of engineers more and more. The automotive industry, says George S. Brady, editor of *Product Engineering*, in the September issue of MECHANICAL ENGINEERING, deserves the credit for being the leader in giving the customer what he desires. Gradually the spirit of making designs that will not only improve products but make them more readily marketable because buyers are attracted to them is pervading all industry. Engineers must recognize this tendency.

MECHANICAL ENGINEERING

Volume 53 — September, 1931 — No. 9

Recent Developments in Army Mechanization

Evolution of Warfare—Tanks—The First Application of Labor-Saving Machines in Warfare—Mechanization Policy of U. S. War Department—Automotive Vehicles Available for Combat Purposes—Problems in Tank Design—Convertible Vehicles—Armored Cars

By JOHN K. CHRISTMAS,[1] WASHINGTON, D. C.

THE story of automotive combat vehicles is the history of arms. This article will describe briefly the development of the latest of modern weapons, the tank and its accessory automotive vehicles.

When a man fights with his fists he does three things: he hits, he protects himself, and he moves about. These three elements are inherent in all fighting, whatever the scale or the conditions. But even before the time of recorded history, savage man found out that a good club could deal a better blow than his fist. Sometime later, some Edison, not recorded in the histories, discovered that a shield is better protection than a bare left arm. Time and taxes went on for perhaps a couple of thousand years, and some young wielder of a club hit on the idea that if he, his club, and his shield got on a horse he would have a big advantage in mobility and shock power over the men in the neighboring enemy tribe. It can be seen that by this time each of the elements of land warfare had made considerable progress in "mechanization." All this took place in prehistoric times.

The Evolution of Warfare

The gradual evolution of the fighting man is too familiar to be repeated here. The high spots in the curve, as when the English foot soldiers at Crecy in 1346 with the first primitive firearms defeated the armored French knights on horseback, are common knowledge. The point to note is the uneven development of the three factors of warfare: Until the World War no one improved on the horse for mobility; protection developed through various shields to the fully steel-armored knight on his armored horse—and then went backward to the unprotected man; only the "hitting power" or fire power developed until we arrived at the deadly artillery and still more deadly machine gun of today.

About the time of Napoleon the infantry musket began to become so effective (both as to range and as to accuracy) that, while individual armor was out of the question, something had to be done to assist or "protect" the attacking troops. Napoleon did it, and "it" was to use a great deal more artillery in an attack to cover the advance of the infantry and the cavalry. Thus originated the artillery duel, defined by some cynics as shooting at each other's infantry. What may thus be called the artillery cycle developed rapidly, field guns increasing rapidly in number, effectiveness, and in the amount of ammunition consumed.

Even as early as in our Civil War such events as Pickett's unsuccessful charge at Gettysburg showed that the last "800 yards" were becoming an almost unpassable "no man's land" for the attacking troops. But all went fairly well with the armies until the World War. Wars are always disillusioning to armies. What happened was mainly this: that the defenders, chiefly because of the machine gun, had such an enormous fire power that they and their fire could not be sufficiently reduced by the attackers' artillery to allow the attacking infantry or cavalry to get to its objective in any effective numbers. The last 800 yards became practically unpassable; stalemate and warfare of attrition ensued.

To overcome this condition, artillery in numbers never heard of before fired quantities of ammunition never dreamed of before. For example, at the Battle of the Somme in 1916 the British artillery fired 4,000,000 shells in 7 days to cover their attacks. The whole Union Army used only about 5,000,000 shells in the *whole four years* of the Civil War. However, the four million rounds fired at the Somme produced no startling victory, and the British casualties numbered tens of thousands. The law of diminishing returns, usually associated with economics, was operating in the case of artillery fire.

[1] Ordnance Department, U.S.A. Capt. John K. Christmas was born in Pittsburgh, Pa., in 1895. He was graduated from Lafayette College in mechanical engineering in 1917, and entered the Regular Army the same year as a Second Lieutenant in the Coast Artillery Corps. In 1918 Captain Christmas served in the American Expeditionary Force with the 60th Artillery (a motorized artillery regiment) in command of Battery A of that regiment in the Meuse-Argonne battle. In 1922 he was transferred to the Ordnance Department and took a post-graduate course in ordnance engineering at Massachusetts Institute of Technology and at the Ordnance School, Watertown Arsenal. From 1924 to 1927 he was engaged in automotive testing at the Aberdeen Proving Ground, Maryland, and in 1928 he was on duty at the Westinghouse Electric Manufacturing Co. Since 1928 he has been in the Automotive Section, Office of Chief of Ordnance, and at present is in charge of automotive design in that office.

Tanks the First Application of Labor-Saving Machines in Warfare

In 1916 the British, taking a page from the book of industry, conceived the idea of applying labor-saving machines to warfare. Their idea was to move infantry into battle in a power-driven vehicle, protected by armor—a sort of armored taxicab. The British Navy under the personal direction of Winston Churchill originated the development of the tank. This is not so odd as it sounds, because navies have been using machinery, i.e., have been "mechanized," since the days of the *Monitor* and the *Merrimac*. With the advent of the tank, two of the three elements of land combat, protection and mobility, were awakened from their sleep of many hundreds of years. The tank was based directly on the caterpillar or track-laying agricultural tractor invented by an American named Holt. Tractors of the caterpillar type are used by the field artillery of our Army today. The name "tank" was given to the first experimental vehicles built in order to mislead spies, but it has remained ever since. The early official name was "landship," and the first one built as a tank was called "Mother."

The tank is a track-laying cross-country automotive vehicle that carries guns whose crews, as well as the tank machinery, are protected by armor; the tank truly is a land battleship.

Like all new things, the early tanks got many a hearty laugh from everybody, including the infantry whom the tanks were intended to help. Selling the tank idea to the British War Office was in some ways as hard as building the tank. Tanks are still getting laughs, but they are neither so frequent nor so loud as they used to be.

Tanks were never used in great numbers during the World War because they were scarce, but principally because their value and mission were not fully understood. However, after the introduction of tanks in 1916, all the larger armies built and used tanks. The Germans never succeeded in making even a fair tank, although they had a few captured British tanks to work from. In one battle the Germans captured a British tank and then sent it back into battle against the British.

Tanks were used by the various combatant armies in ever-increasing numbers, a high point of their employment being reached by the British in the Battle of Amiens on August 8, 1918, when a brilliant victory was achieved which was clearly due to the use of tanks. In that battle the British employed, however, only 415 tanks. Compared in money or labor value to that of the ammunition expended, this quantity of tanks was small. Speaking of this battle and some others during the close of the World War, Ludendorf, the great German general, said: "Mass attacks by tanks and artificial fog remained hereafter our most dangerous enemies." How far the military leaders of the World War had gone in their belief in tanks may be judged from the fact that the American Army alone had on order, for use in the contemplated spring offensive of 1919, 23,405 tanks! But the World War stopped too soon for the value of the tank to be proved conclusively. The value of the tank in warfare is therefore in the same more or less debatable position that military aviation now is. Regarding tanks and the general idea of mechanization there will certainly be hot words and fierce articles on both sides, and probably the whole question will not be conclusively settled until the next war.

Admiral Mahan, the great American naval historian, epitomized this situation thus:

> The student will observe that changes of tactics have not only taken place *after* changes in weapons, which necessarily is the case, but that the interval between such changes has been unduly long. This doubtless arises from the fact that an improvement of weapons is due to the energy of one or two men, while changes in tactics have to overcome the inertia of a conservative class; but it is a great evil. It can be remedied only by a candid recognition of each change.

However, as a result of the lessons of the Experimental Mechanized Force assembled at Fort Meade, Md., in 1928, the War Department was able to set up a permanent mechanized force in the autumn of 1930 for the principal purpose of developing tactics for mechanized units. The present Mechanized Force is a small unit equipped with a great variety of experimental automotive equipment, a large part of which is modern. Intensive experiments in the tactical use of such equipment have been and are now going on with this force at Fort Eustis, Virginia, under Col. Daniel Van Voorhis, the force commander.

Mechanization Policy of the U. S. War Department

The studies of the War Department have recently resulted in a revised mechanization policy being laid down by the Secretary of War. This reaffirms the old functions of the various arms: briefly, infantry to hold and assault; artillery to support; and cavalry to reconnoiter, raid, out-maneuver the enemy, and clinch the battle at critical moments. (These functions refer principally to open warfare and not to trench warfare.) The cavalry retains its old functions and missions, but is to be modernized by substituting largely for the troops on horseback armored cars and combat cars (or fast light tanks).

Mechanization involves the use of machines to replace or augment the soldier (and the horse) *in combat*. Without entering into an extended discussion of the merits and demerits of mechanization, it is at least safe to say that mechanization will result in greatly decreased casualties to personnel, while making possible a large increase in fire power per man risked in battle. For instance, a light-tank company has about 15 times as much fire power per man risked in battle as an infantry company, and this takes no account of the much greater tactical mobility of the tank unit. Fire power protection, and mobility are the three elements involved, but little can be done to augment the first two elements unless the third be successfully improved. Mechanical mobility in combat, that is, an automotive vehicle to carry guns and armor, is therefore the crux of the mechanization problem.

Automotive Vehicles Available for Combat Purposes

This might at first sight seem simple since we have the automobile, a highly perfected article. However, this is not the case, because battles rarely take place on roads—the only place an ordinary wheeled vehicle is sure to be operable. Having regard only to tactical mobility or ability to move in the battle area when not on roads, let us list, as in Table 1, the various types of automotive vehicles available, *in order of their tactical mobility.*

It is of course highly desirable that a combat vehicle have good mobility both tactically and strategically. (Strategic mobility refers to moves outside the battle area, and usually on roads.) Such combinations are only found in types 3, 4, and 5. It can be seen from Table 1 and accepted as reasonably certain that only a vehicle using some form of caterpillar track will have satisfactory tactical mobility while only one operating on wheels will be satisfactorily mobile on the road. Since tactical mobility is of greater importance, the Ordnance Department has since the World War devoted particular attention to work on tanks and other vehicles of the fast, full track-laying or caterpillar type.

This work is particularly important because there is no commercial counterpart. Commercial tractors now have a maximum speed of about 5 miles per hour, and there seems to be practically no demand for higher speeds. The development of high-speed track-type tanks may be seen from Table 2.

TABLE 1 TYPES OF AUTOMOTIVE VEHICLES AVAILABLE FOR COMBAT PURPOSES

(In Order of Mobility)

Item	Type	Strategic mobility (on roads)	Cost	Availability in quantity	Tactical speed,[1] m.p.h.	Status of development
1	Special track-type tractor	Poor	High	Poor	20	Good
2	Commercial track-type tractor	Poor	Low	Excellent	5	Excellent
3	Convertible vehicle (wheel and track)	Good	High	Poor	20	Poor
4	Portée[2]	Good	Medium	Excellent	20	Excellent
5	Half-tracked vehicle	Fair	Medium	Poor	15	Fair
6	Multi-wheel drive (6 or more)	Excellent	Medium	Poor	20	Fair
7	6 wh. 4-wheel drive with detachable tracks	Excellent	Medium	Poor	20	Fair
8	4-wheel drive	Excellent	Low	Poor	20	Good
9	2-wheel drive	Excellent	Low	Excellent	20	Excellent

[1] Maximum tactical speed given as 20 miles per hour as this is considered maximum practical speed across country.

[2] "Portée" refers to the use of a commercial tractor for tactical mobility, the tractor being carried in a truck when necessary for strategic mobility.

TABLE 2 DEVELOPMENT OF HIGH-SPEED TRACK-TYPE TANKS

Type	Year built	Weight, tons	Max. speed, m.p.h.	Engine, hp. per ton	Armor	Armament	Fire power, per ton weight, lb. per min. per ton
Six-ton	1918	7½	6	6.5	Against cal. .30 A.P.	1 37-mm. gun or 1 mach. gun	1.6
Mk. VIII	1918	44	5	7	Against cal. .30 A.P.	2 6-pdr. 5 mach. guns	4.1
Med. 21	1922	23	10	8	Against cal. .50 A.P.	1 6-pdr. 2 mach. guns	3.1
Med. T-1	1926	23	12	10	Against cal. .50 A.P.	1 6-pdr. 2 mach. guns	3.1
Light, T1E1	1928	7½	20	18	Against cal. .30	1 37-mm. gun 1 mach. gun	5.9
Med. T-2 (Figs. 4 and 5)	1930	15	22	20	Against cal. .50 A.P.	1 3 pdr. gun 1 37-mm. gun 2 mach. guns	10.1

Table 2 does not show, as they are qualities more difficult to evaluate numerically, that the latest models have much greater mechanical reliability and a much longer mileage life than the World War models. The Medium Tank, T-2, can be counted on to run continuously for eight hours; it is positively ventilated; driving fatigue is reduced by the use of a vacuum booster to operate the steering clutches and brakes, and four gear speeds are provided. The Light Tank, T1E1, has run over 2000 miles without an overhaul.

Problems of the Tank Designer

The tank designer is confronted with the problem of making an intelligent compromise between speed, power, armor protection, armament, and reliability; an increase in one of these means a reduction in one or more of the others. For example, the curve in Fig. 1 shows how the power requirement increases with speed in full track-laying vehicles. The demands for high speed and ample reserve power without undue weight have made it necessary to use, in tanks, airplane, and passenger-car engines; engines of a class not otherwise suited to this heavy duty.

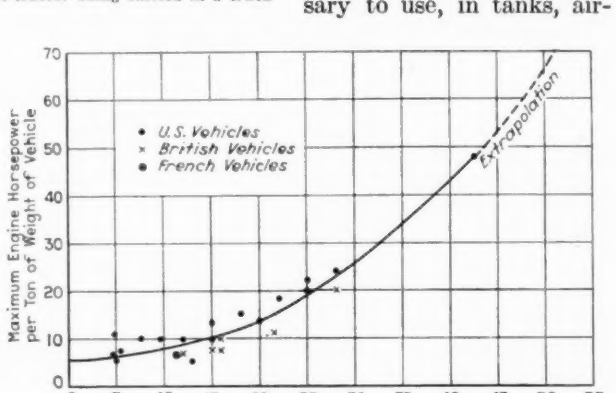


FIG. 1 CURVE SHOWING RELATION OF POWER REQUIRED TO MAXIMUM SPEED FOR TRACK-LAYING VEHICLES

(Data plotted from actual tanks and other track-laying vehicles. The data concerning U.S. vehicles are the most reliable, and are in most cases the results of actual dynamometer tests.)

Armor plate weighs 40 lb. per sq. ft. per inch of thickness. At point-blank ranges the following thicknesses are required to stop various bullets:

Caliber .30 service bullet	¼ in.
Caliber .30 armor-piercing bullet	⅝ in.
Caliber .50 armor-piercing bullet	⅞ in.

Armor plate may fairly be said to be the millstone around the tank designer's neck. For example, in the Medium Tank, T-2, the armor plate weighs 5 tons, or

exactly $^1/_3$ of the total weight. This weight is much beyond that needed for structural strength, the primary function of the armor plate. Slow but steady progress is, however, being made in the resistance of armor plate to penetration.

The critical parts of any track-laying vehicle are its tracks and suspension. Improvements in steels and in heat treatments have resulted in tracks which may be counted on to run 2000 miles at high speeds, when they may be made practically new by replacing the hardened steel bushings and pins in the hinged joints. Tests have also shown the advantage for high-speed tracks of a short pitch, 3 to 4 in. per track shoe or link, as compared to the 7 to 10 in. formerly used.

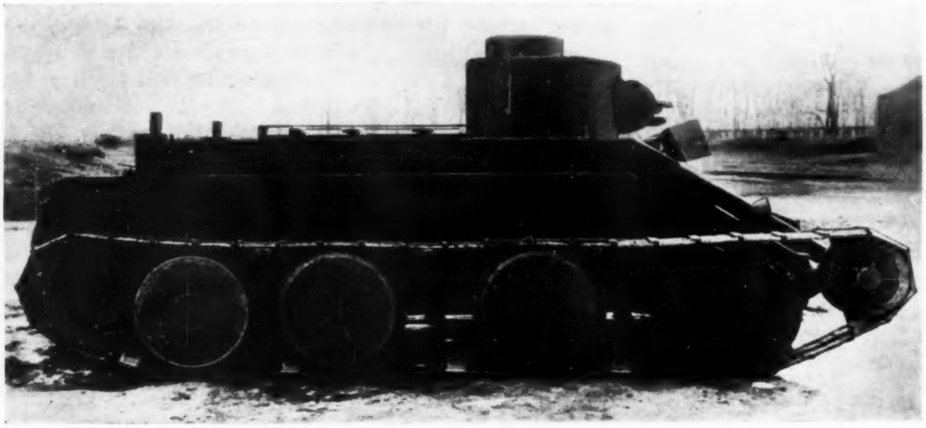


Fig. 2 The Christie Convertible Tank

Because of the uneven ground on which a tank must operate, suspensions are usually individual; that is, each or each group of weight-carrying rollers or wheels is suspended independently of the others. In the Medium Tank, T-2, the rollers are in pairs mounted in bogies, which, in turn are supported each by two vertical concentric helical springs. The most critical element in the whole suspension is the anti-friction bearing in the track roller. It carries a large vibrating load at a high rotational speed and is difficult to protect by a mechanical closure from dirt and moisture. The solution of this may be to use track rollers of larger diameter equipped with solid rubber tires.

A critical matter in any tank is proper cooling of the engine, due to its being closely covered and due to the limitations on the size and weight of the radiator and cooling accessories. Good cooling with restricted cooling systems has been achieved by the use of a mixture of water and ethylene glycol in equal parts. Thus raising the boiling point increases the heat absorption and the subsequent rate of radiation of the coolant. Oil radiators, air cooled, for the engine oil are also used to advantage.

The earlier heavy tanks were built with epicyclic transmissions on the theory that such a transmission allows the load to be picked up better when starting. (A track-laying vehicle does not usually gather momentum, as does a motor car, to allow successive gear shifts.) But practical difficulties with the brakes in the epicyclic transmission have led in the latest tanks to the use of heavy 4-speed spur-gear transmissions of the constant-mesh type with jaw clutches for shifting gears. These with a heavy, dry, multiple-disk main clutch have been found satisfactory, although they require considerable skill to operate.

The steering of a full track-laying vehicle may be accomplished in one of the following general ways:

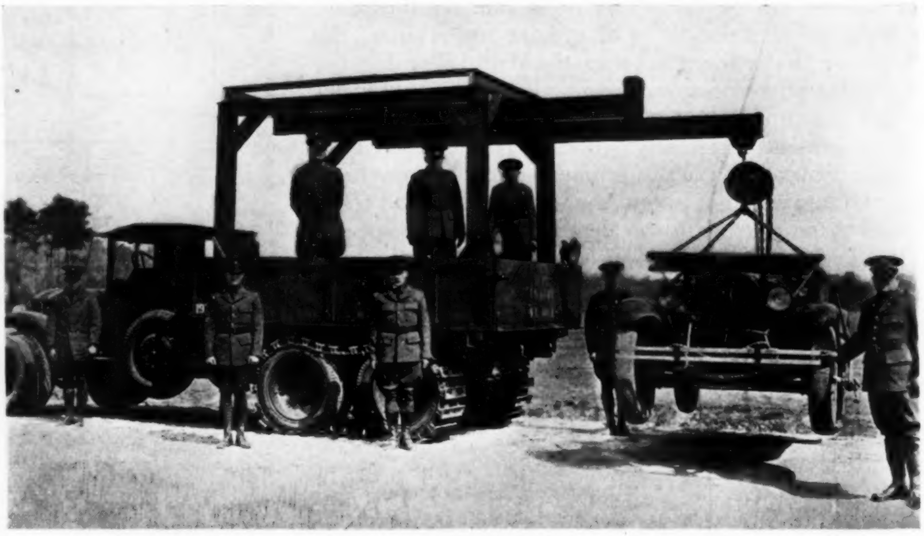


Fig. 3 Six-Wheeled 4-Wheel-Drive Wrecking Truck Showing Removable Half Track on Rear Driven Wheels

a By the use of a differential between the two tracks and braking the track on one side, thereby causing the tank to turn to that side

b By the use of a controlled epicyclic unit in the final drive for each track, thereby making possible variations in the relative speeds of the two tracks

c By the use of steering clutches, that is, by in-

stalling in the final drive for each track a clutch; in turning, the clutch on the side to which it is desired to turn is disengaged while the other track pushes the vehicle around. The turn may be sharpened by applying a brake to the disengaged side.

Tests and experience to date indicate the considerable superiority, at least as regards longevity and reliability, of the steering-clutch type of steering. This experience is based principally on slow-speed track-laying vehicles, but it appears likely that, for the steering of track-laying vehicles at speeds from about 15 miles an hour upward, one of the other systems mentioned may eventually be found preferable. However, if one of these systems is to be used the existing military requirement that a track laying vehicle be able to pivot or turn in place must be modified, as this can only strictly be accomplished with the steering-clutch type of control with a brake on each steering clutch.

FIG. 4 MEDIUM TANK, T-2

WEIGHT REDUCTION A DESIDERATUM

As has already been stated, the principal problem confronting the tank designer is the reduction of weight. One way in which this might be accomplished is by the use of air-cooled instead of liquid-cooled engines. As it is not the policy of the Ordnance Department to use its limited funds for the development of engines, the air-cooled engine for tank use must come from the automotive or airplane industry. Last winter an experiment was initiated in this direction by installing in six light tanks a 6-cylinder air-cooled passenger-car engine. Before installation the following principal changes were made to these engines: the diameter of the blower was increased about 16 per cent; an external oil radiator installed, cooled by the cooling air; and dry-sump lubrication (as used in all tank engines due to the extreme angles at which they may operate) was installed, cooled with oil pumps of excess capacity. These vehicles have been in service since March of this year, but as they have not yet been operated any considerable time nor in extremely hot weather, it is too early to comment on the results of this experiment.

A considerable reduction in the weight of tanks and related vehicles has been made possible by the use of electric-arc welding. This saving occurred not only in the substitution of welding for riveting in the fastening of structural plate and armor plate, but also in the building up by welding from high-grade steel of parts which were formerly made of cast steel and which were therefore necessarily considerably heavier. The use of welding also results in a more finished appearance at a reduced cost, but it is not definitely known yet whether armor plate can be welded under all conditions. Tests already made indicate that as far as resistance to bullets goes, welding may be used with reasonable success. There remains some question as to whether the welding does not so affect the armor plate as to reduce its structural strength near the weld. Another means of saving weight, which is being increasingly used, is the employment of aluminum and its alloys. The first step in this direction was the use of aluminum, both cast and rolled, for floor plates, ammunition racks, and minor parts not subjected to extreme wear or strain. With the recent improvements in alloys of aluminum, and the fabrication of drop-forged aluminum alloy parts, the use of aluminum has been extended. A vehicle is now being built in which is being used the highest grade of aluminum alloys obtainable for a cast-aluminum transmission case and other important parts. Some work has also been done with a forged-aluminum track shoe with very promising results.

CONVERTIBLE VEHICLES

With respect to the convertible type of vehicle mentioned in Table 1, the Ordnance Department in 1920 began experimenting with vehicles of this type developed by J. Walter Christie. As is so often the case with a piece of equipment designed for a dual purpose, these vehicles were not a success. A convertible vehicle is necessarily an engineering compromise of major proportions; and when it is remembered, in addition, that one element of the compromise, the track-laying vehicle, is still under rather rapid development, it can be seen that convertible vehicles are still open to considerable question from an engineering standpoint; compromises in their tactical value will probably have to be accepted. In January, 1931, Mr. Christie again submitted for test

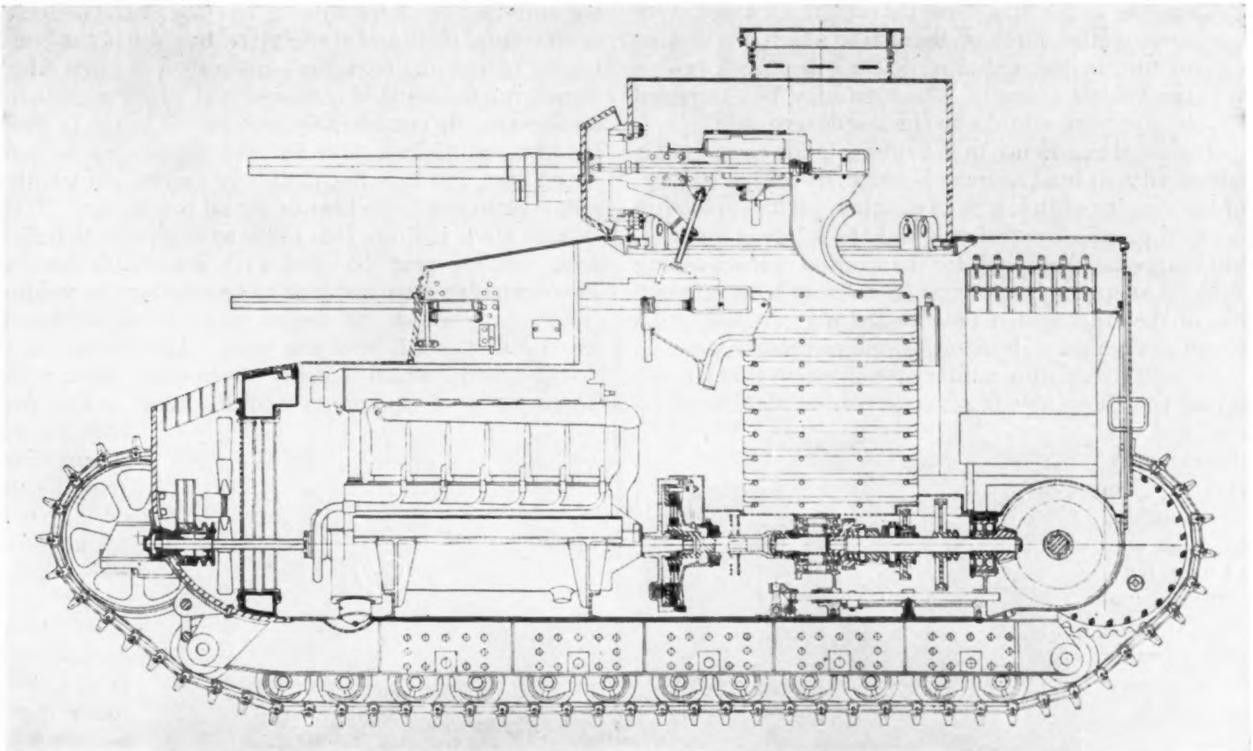


Fig. 5 Longitudinal Section of Medium Tank, T-2

by the Ordnance Department a convertible vehicle, a medium tank weighing 10 tons (Fig. 2). This vehicle operates on the road on four pairs of independently sprung wheels equipped with dual solid-rubber tires; the rear pair of wheels only is driven by a conventional chain drive, while steering is accomplished by the front wheels, as in an automobile. When operating as a full track-laying vehicle a drop-forged steel track, weighing 810 lb. per side, is applied over the wheels, a small idler in front, and a track-driving sprocket in rear. The tank is powered with a Liberty 12-cylinder V water-cooled tank engine of 330 hp.; as the engine and the other units of the power plant are located in the rear, there is only room in front for a crew of two men, although the vehicle is 18 ft. long. In the limited test to which this vehicle was submitted it showed considerable improvement over its predecessors of the same type; a sustained speed of 20 miles per hour across country was achieved on its tracks and 40 miles per hour on its wheels. Questions still remain as to the reliability and durability of this type, and its behavior in hot weather, on extremely rough terrain, and under conditions of heavy engine torque; all with average operators. These matters can best be determined by extensive service tests, with a view to which the War Department is now having built a number for such service tests.

Fig. 6 Self-Propelled 75-Mm. Howitzer
(Maximum speed, 22 m.p.h.)

Armored Cars

While the tank and vehicles of its type form the backbone of the mechanized force, there exists also a large function for wheeled vehicles of the better types. This is particularly true of what is known as the "armored car," a wheeled vehicle lightly armored and armed with machine guns only. Such a vehicle has a great strategic mobility and considerable fire power. It is therefore of great value in long-distance reconnaissance patrols, raids, and similar missions which can be accomplished primarily on the road. In order to give these vehicles, which have the advantage of

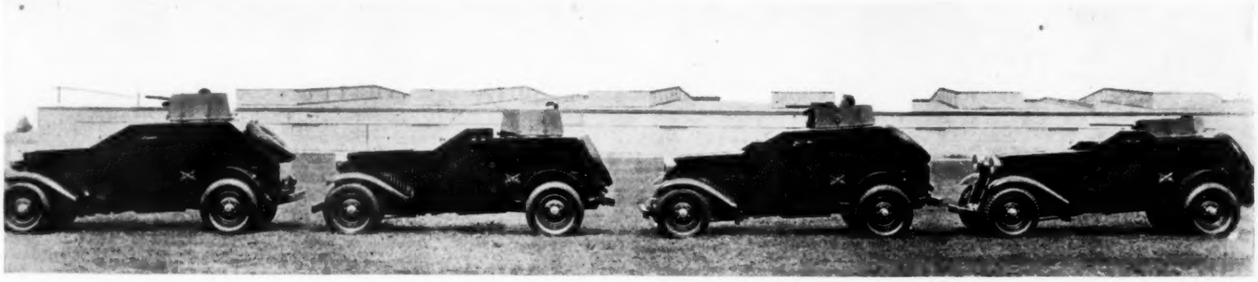


FIG. 7 MEDIUM ARMORED CARS ON COMMERCIAL CHASSIS

cheapness and great commercial availability, a measure of tactical mobility, various means have been employed. The most successful to date have been the 6-wheeled vehicles with the four rear wheels driven, of the type now often seen on the highways transporting heavy loads. The point of divergence between the commercial development of the 6-wheeler and the military 6-wheeler is that the commercial 6-wheeler is employed to transport very heavy loads, whereas the military requirement is for a light 6-wheeler where the six wheels are employed to obtain greater flotation and traction off roads. As a means of further increasing the off-road mobility of the 6-wheeled vehicle, experiments have been conducted with light removable metal tracks fitted over the four dual pneumatic-tired rear wheels (Fig. 3). Such tracks have been found very effective in increasing both the flotation and traction of 6-wheeled vehicles off roads. But their use must be restricted to the occasions when they are actually required, as such tracks have a comparatively limited life, measured by the hundreds rather than the thousands of miles.

In a true mechanized force, there must, in addition to the tanks and armored cars, be supporting artillery, chemical mortars, wire-laying vehicles, ammunition carriers, radio vehicles, and other vehicles carrying special equipment. While these vehicles may at first sight appear to be special problems, their development is comparatively simple and it is almost entirely dependent on the development of a successful chassis: track-laying, convertible, or wheeled, as the requirement may be. While some special vehicles of this type have been produced for the use of the Mechanized Force, the basic engineering question remaining in the development of mechanized equipment lies in the development of a satisfactory high-speed track-laying chassis, *convertible if possible*, so as to add to its tactical mobility the maximum of strategic mobility.

From the present experience of the Ordnance Department it does not appear that this problem will be solved over night or by any specific invention, but rather by the continuation of the good progress already made in this rather complicated phase of automotive engineering. Better metals, better engines, and better processes combined with continual improvements in design based on accumulated experience will, it is hoped, continue to make for improvements at the rapid rate already attained. In this important work the Ordnance Department has depended and will continue to depend, to a large extent, on the general and specific support of the engineers of American industry. Such improvement as there has been in the limited number of mechanized vehicles developed by the Ordnance Department may in a large measure be ascribed to the rapid progress in industry and to the contact maintained therewith through the Society of Automotive Engineers Ordnance Advisory Committee, of which Col. A. F. Masury is chairman. Due to the preeminence of the United States as an industrial nation and its unlimited facilities for quantity production, the increasing mechanization of armies should work to the benefit of our country in case of difficulties with other nations.

Engineering Education

PREMATURE specialization cramps the imagination and is destructive to the length and breadth of mental vision. Give me a youngster who has had his foundations of belief widely and deeply laid, and I will back him, at long odds, to overtake and surpass at his own game one of equal native intelligence, who has had his imagination cramped by premature specialization.

In a university course of engineering, instruction should primarily concentrate on teaching those essentials which, if not acquired at that stage, never will be acquired. Technicalities which will automatically be picked up in a student's subsequent career are useful as stimulating interest, but apart from this they are of secondary importance. Education does not consist in the memorization of a number of facts and formulas, useful as these may be when leavened with intelligence. Education at its best should aim at something much deeper and more lasting, and the good of education is the power of reasoning, and the habit of mind which remains, when all efforts of memorization have faded into oblivion.

By following this ideal our engineering students, when they leave our hands, are necessarily lop-sided creations, and we must leave it to their subsequent employers to rectify this lack of symmetry. We hope for sympathetic treatment in this process. We hope that it will be done by filling in the hollows rather than flattening down the excrescences.—From "Cambridge as a Place of Education," by Prof. C. E. Inglis, in *The Engineer*, July 17, 1931, page 71.

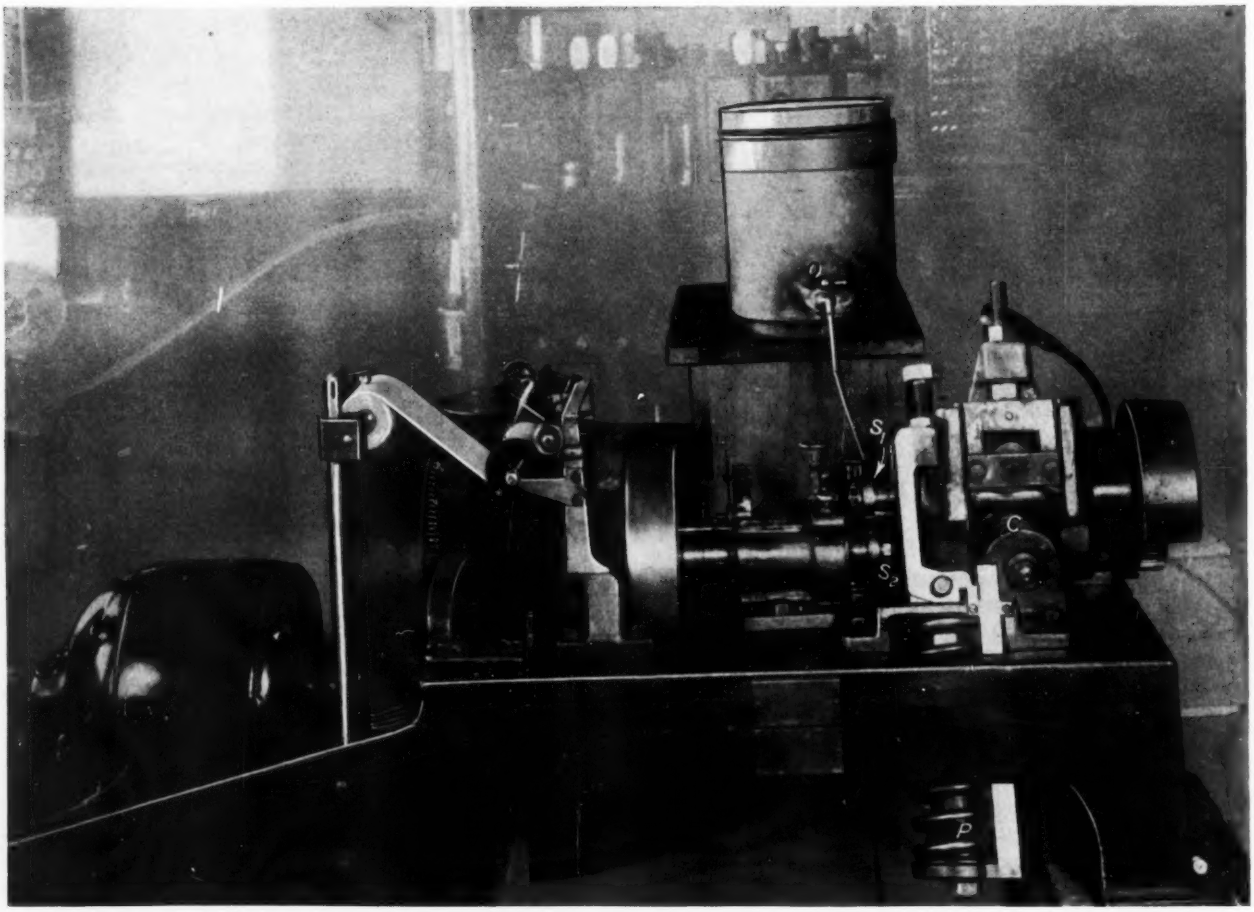


FIG. 1 AMSLER WEAR-TESTING MACHINE

(The surfaces of the specimens S_1 and S_2 move in the same direction but at different speeds, with lateral oscillation produced by cam C, and under contact pressures controlled by spring P. Friction is recorded on torque indicator at left. In tests with lubrication the oil is supplied from reservoir O.)

The Wear of Metals[1]

Definition and Classification of Wear—Mechanism of the Wear of Metallic Surfaces—Importance of Wear in Engineering Design and Service—Methods of Protection Against Wear—Evaluation of Wear Resistance by Laboratory Tests—Coordinated Wear Research

BY LOUIS JORDAN,[2] WASHINGTON, D. C.

ONE of our metallurgical journals very recently carried a statement on its editorial page to the effect that the most embarrassing question a metallurgist can be asked is how a given alloy will withstand service involving repeated stress, wear, corrosion, or high temperature. The same editorial continued, "We probably know less about the mechanism of wear or of how to test the wear resistance of a metal than we do about other kinds of severe service." If this is a true picture of the state of affairs with respect to the wear of metals, then there is certainly a challenge to the metallurgist to develop the fundamental laws governing the wear of metals and a challenge to the engineer to make certain that he has available data that will allow him to evaluate the wear factor in the design and operation of equipment.

Some of the divisions of The American Society of Mechanical Engineers have lately shown an active in-

[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] Senior Metallurgist and Chief of the Section of Thermal Metallurgy of the U. S. Bureau of Standards, Mr. Jordan is a graduate of Bates College and of the University of Illinois. Prior to joining the staff of the Bureau of Standards in 1917 he was employed as chemist with the Chicago testing laboratories of Sears, Roebuck and Company, and as research chemist with the U. S. Industrial Alcohol Company in Baltimore. From 1920 to 1930 he was chief of the section of chemical metallurgy of the Bureau of Standards.

terest in the problem of the wear of materials, and have given some consideration to possible methods of encouraging further and better-coordinated research on the subject. It was therefore suggested that the Society might be interested in a paper which would adequately present the importance and the present state of knowledge of the wear of metals.

The present paper, however, must at once disclaim any pretense of being the desired adequate presentation of a field so broad and so little understood. It hopes only to make some tentative definitions and classifications of various types of wear of metals; to offer a few comments on the possible mechanisms of wear; to indicate rather sketchily the importance of the part played by the wear of metals in engineering design and service; to recall various means that are employed for the lessening of or protection against wear; to discuss the extent to which the testing or research laboratory is able to predict from accelerated tests the relative wear resistance of metals; and, finally, prompted by a suggestion that has been made a number of times both verbally and in the literature, to raise the question as to whether the problem of the wear of metals is of such a nature, magnitude, and importance that any formal organization and coordination of interested research agencies might bring about more notable progress in furthering knowledge in this field.

I—Definition and Classification of Wear

Wear of a metal may be defined as the unintentional removal in service of the surface of a metal through the action of frictional forces. Wear may thus be distinguished from grinding, polishing, lapping, or "wearing-in" in that all these latter involve intentional removal of metal surfaces.

Wear of metals has been classified in several ways. For example, the classification may be made on the basis of the nature of the two contacting materials between which the frictional forces causing wear are developed. In such a case the two major types of metal wear are:

1 Metal against metal
2 Metal against non-metal or abrasive.

In other instances wear has been classified on the basis of the type of frictional forces set up between the wearing materials. The main classes of wear are then:

3 Wear under rolling friction
4 Wear under sliding friction.

With either of these systems of classification, two additional subdivisions of each type of wear are often listed, namely,

a Wear in the presence of a lubricant
b Wear in the absence of a lubricant.

Other conditions being equal, it appears somewhat doubtful whether the presence or absence of a lubricant necessarily indicates two different types of wear. Rates of wear are certainly influenced by lubrication, but the actual type of wear probably remains the same. Indeed, most investigators are practically unanimous in their opinion that when adequate lubrication is present, wear is almost negligible.

The foregoing classifications are obviously based on the conditions of service causing wear. It might be expected that a logical and more fundamental classification could be made on the basis of the detailed physical and chemical actions at the surface of wearing metals. Such a classification is, however, difficult, due to the lack of really fundamental knowledge of the nature of wear. In spite of this situation, it is proposed to suggest a tentative classification on the basis of the mechanism of wear. Such a classification must admittedly be largely based on speculation, and will doubtless have served its purpose fully if discussion is aroused.

II—Mechanism of the Wear of Metallic Surfaces

We quite naturally, and without any particular consideration, use the term "abrasion" in speaking of the action of a finely divided solid, such as sand, in wearing a metal surface, whether the sand impinges on the metal surface borne by a gas or by a liquid stream, or sand, as a portion of a grinding wheel or abrasive paper, is drawn across the surface of the wearing metal. The lexicographer tells us that "abrasion" is from the Latin *ab-* and *rado,* meaning literally to "scrap from" or "rub off."

When there is occasion to speak of the wearing away of a metal by jets of steam or other fluids, which are at least relatively free of solid particles, or of the "cutting" of valves and valve seats by flowing liquids or gases, there is little hesitation in calling this wearing action "erosion." Again turning to the dictionary, erosion, from the Latin *e-* and *rodo,* means literally to "gnaw off" or "eat away." The word is sometimes defined specifically as signifying "a corrosive attack."

When we find that bearing surfaces such as valve heads and valve seats are roughened after periods of use involving alternate contact under pressure followed by separation, we may note that small particles appear to have been picked out of one surface and possibly rather firmly attached to the other surface. This type of wear, we would state rather confidently, is an example of "galling."

We may therefore say that there are at least three commonly recognized types of wear: wear by abrasion, by erosion, and by galling. Possibly these three types of wear may be defined somewhat as follows:

Wear by Abrasion involves the mechanical distortion of the surface layers of the metal, followed by the removal of these distorted layers by frictional forces, which forces are generally restricted to those developed between the wearing metal and solids.

Wearing by Erosion involves an alteration of the surface layers of a metal by chemical attack, followed by the removal of metal or of the products of chemical reaction by frictional forces, which forces are restricted to those developed between the wearing metal and flowing gases, or liquids, or vapors.

Wear by Galling involves the adhesion or cohesion

of localized areas of two bearing surfaces of metal, followed by the tearing out of small fragments from the one surface or the other as relative motion between the two bearing surfaces continues or is initiated.

It is to be noted that in each of these three types of wear there are two stages: first, some sort of mechanical or chemical modification of the metal surface, and second, the actual removal of material from the wearing surface.

It is probable that wear under actual service conditions rarely is due to any single one of the three causes mentioned above. For example, the initial rapid wear of two metal surfaces which are relatively rough as prepared in the machine shop, even though finish ground, may quite possibly be wear purely by abrasion. After this initial "wearing-in" period when abrasion has produced surfaces free from the irregularities of machining, wear may continue at the same or a slower or faster rate by combined erosion and abrasion. Wear is then a function of the nature of the contacting surfaces, pressure, and relative motion alone—the influence of the original surface finish has been eliminated. In the subsequent stages of wear the wearing surfaces may oxidize, thus being roughened by a reaction characteristic of the first stage of erosion wear; this oxidized surface may then be removed by friction developed between the solid bearing surfaces, the characteristic second stage of abrasive wear; and further the oxide particles thus removed may act as a fine abrasive and cause further roughening of the bearing surfaces by mechanical means as in the first stage of pure abrasion.

It is this combined action of erosion in the presence of oxygen and of abrasion that Fink[3] has recently studied. He came to the conclusion that oxidation was not a secondary phenomenon in wear, but was rather one of the main factors. Under his experimental conditions, namely, with combined sliding and rolling friction, metal-to-metal contact, and no abrasive, he found wear was absent when oxygen was completely excluded. It is doubtless going too far on the present evidence, however, to suggest that metals do not wear in the absence of oxygen.

Fink has analyzed the wear of metals as consisting of three components, namely,

1 Mechanical removal of particles
2 Cold-hardening process, and
3 Wear oxidation.

He thus groups together under his first component the second stage—the stage of the actual removal of material—of all types of wear. Cold hardening or work hardening is, however, not the only possible mechanical agency for bringing about the distortion of the surface of the wearing metal. This distortion may be caused by the cutting or gouging action of abrasive particles, or may result from the phenomenon of "galling" as already described. Wear oxidation may, conceivably, be so defined as actually to cover all the chemical reactions which are grouped together under the first stage of erosive wear as defined in the classification of types of wear proposed in this paper. That is to say, if we start with a clean *metallic* surface the chemical union of metal atoms of this surface with any non-metallic element to form compounds in which the metal has a positive valence, be this element oxygen, nitrogen, carbon, or sulphur, is oxidation of the metal in the eyes of the chemist. Wear oxidation defined in this comprehensive way then denotes almost any mechanism of wear that involves chemical attack of the metal surface.

But all of this discussion of the mechanism of metallic wear is based largely on supposition of what may take place. It is to be considered as an enumeration of some of the various factors which the research worker should attempt to study separately in developing fundamental knowledge of the wear of metals.

III—Importance of Wear in Engineering Design and Service

It is almost unnecessary to take the time to present arguments that the wear of metals plays an important part in engineering design and service. We are all only too familiar with bearing knocks, piston slaps, or scored brake drums in our automobiles, faults that result from the wear of metals either against other metals or against non-metallic brake linings, and any one of us who has any interest in the design, production, or service of any manufactured article could name and describe wear phenomena that cause serious trouble or require special attention to insure elimination.

The wear of metal against metal occurs wherever a shaft rotates on bearing metals, or on roller or ball bearings; piston rings operate against cylinder walls; valves press or hammer against valve seats; gears mesh; chain drives operate over sprockets; metal wheels roll on rails or are stopped by application of metal brake shoes; metal gages are used to measure dimensions of other metal objects; metals are drawn, extruded, or swaged in metal dies; and metal-cutting tools, drills, or saws are used in machining or cutting metals.

There are almost innumerable similar examples of wear of metals against non-metals. Metal cutting tools wear, often excessively, when cutting non-metallic materials; the wear resistance of a metal cutting edge plays a major part in determining how long "sharpness" is retained by all of the countless varieties of knives, from the surgeon's knives and microtome and razor blades up through the carving knife, the lawn-mower blades to the cutting knives of reaping and harvesting machinery and the cutting and trimming knives of the paper mill and the big modern printing establishment. Examples of the wear of metals against non-metals also exist in the case of printing plates or rolls making thousands of impressions on paper; metal spinnerets forming fine threads from cellulose solutions in the production of rayon; those parts of excavating, crushing, grinding, mixing, road-making, and farm machinery which operate in contact with rock and dirt; skid

[3] Max Fink, "Wear Oxidation, a New Component of Wear," Trans. Am. Soc. Steel Treating, vol. 18 (1930), pp. 1026–1034.

chains which rub and pound against ice, dirt, and rock; and extrusion dies used in the forming of clay mixtures for brick, tile, porcelain, and other ceramic products.

In many instances both metal-against-metal and metal-against-non-metal wear conditions exist simultaneously. When non-metallic dirt has opportunity to penetrate between metallic bearing surfaces the normal rate of metal-to-metal wear is often enormously accelerated. Such, for example, was the case a few years ago when an automobile engine must needs use for its carburetor air intake the dirt-laden atmosphere over a heavily traveled dry and dusty road.

Thus far the rôle of wear in engineering design and service has been pictured as entirely an evil to be avoided. It should be pointed out, however, that at times a certain amount of wear or the existence of severe wear conditions is advantageous. The great difficulty is that it is not possible to stop wear at will at any particular stage. The "wearing-in" period for metal bearings may result in a better fit between journal and bearing than is possible with most of our high-speed, mass-production manufacturing processes; rayon spinnerets produce the highest grade, smoothest fibers only after a "wearing-in" period in spite of the greatest of pains taken in finishing and polishing the spinnerets during their manufacture; and, anomalous as the statement may seem, the well-known Hadfield manganese steels exhibit their best resistance to wear only when they are placed in service under certain types of very severe wearing conditions.

The cases in which wear is an advantage are, however, relatively very few as compared with those in which it is an unmitigated evil. Therefore methods of protection against wear are next to be considered.

IV—Methods of Protection Against Wear

Wear is a surface phenomenon. Protection against wear is therefore another case of "Save the surface and save all." Probably the most generally applicable method of protection, at least in conditions which involve metal-to-metal wear, is efficient lubrication. When lubrication is complete there need be no actual metal-to-metal contact; a continuous film of lubricant separates the metal surfaces which would otherwise be in contact. Such being the case, and if the lubricant is free from solid particles, there generally is no opportunity for mechanical distortion of the metal surfaces or for "galling" between the two surfaces. Therefore the first stage of wear by abrasion or by galling cannot occur, and wear of neither of these types is possible. Chemical attack of the separated metal surfaces by some constituent of the lubricant may be and is guarded against in the control of the composition of the lubricant, so that the first stage of wear by erosion is also unlikely. Thus all types of wear appear to be nearly if not quite eliminated when the supply of a suitably chosen lubricant is sufficient in quantity and is supplied continuously at all times to a properly designed bearing.

It is largely because this perfect lubrication is not always realized in practice that the wear of metals in metal-to-metal service continues to be of interest. Consequently it is necessary so to design and select materials that failure of lubrication shall result in the minimum of damage by wear.

Frequently the problem of protection against wear resolves itself into a choice as to which of two contacting surfaces shall suffer the major portion of the wear. Both contacting surfaces would normally suffer wear, and the choice must be made as to which of the two is the less expensive or the more easily replaced. This part is then so designed and constructed of such materials as to suffer the greater share of the wear, protecting and giving longer life to parts which are more expensive or less readily renewed.

In making a choice of anti-friction or wear-resistant materials there are available ball and roller bearings, bearing metals, hardened-surface metals, and superhard alloys.

Ball and roller bearings are to be considered rather as mechanical devices for reducing friction between moving parts than as materials particularly resistant to wear. They do, however, function so as to reduce the possibilities of metal wear: Lubrication is less essential and is rather more easily maintained than with white-metal or bronze bearings; the high hardness, strength, and elastic properties both of ball or roller and of race make mechanical distortion of the contacting metal surfaces difficult; and the purely rolling friction of the ball or roller bearing is far less severe than sliding friction in causing wear.

The bearings most generally used are made of the white-metal bearing alloys and the bearing bronzes. The white-metal bearing alloys are either tin-base or lead-base alloys, relatively soft, and belong to the class of materials which are selected to suffer wear or other injury, and to permit ready replacement in the case of failure of lubrication. Bearing bronzes are lead-containing brasses or bronzes and function in quite the same way as do the white-metal bearings, except that the bronzes have somewhat greater mechanical strength and are therefore suitable for more severe service.

A rather different type of bearing bronze is the so-called self-lubricating bronze, usually a bronze containing free graphite, which may also be impregnated with oil.

Under many conditions in which wear resistance is required of the surface of a steel it is also very essential to have the body of the wear-resistant part relatively soft, ductile, and resistant to shock. This end is frequently accomplished by introducing additional carbon into the surface layers of a rather ductile low-carbon steel. By means of a suitable quenching treatment there is then produced an article with a very hard, high-carbon steel surface, which has desirable wear-resistance properties, with the interior remaining the original ductile low-carbon steel.

Carburizing and case-hardening are the oldest of the methods at present available for producing hard, wear-resisting surface layers on a relatively softer metal. In recent years three additional methods have come

into use, namely, chromium plating, nitride hardening, and "hard surfacing" or "overlaying."

Chromium plate, in thicknesses of only a few ten-thousandths of an inch, has been very effectively employed for increasing the wear resistance of printing plates, of plug gages, of metal rod- and tube-drawing dies, and in many other applications. Electroplated chromium, in addition to being very hard and resistant to abrasion, appears to have another quality, difficult of any quantitative evaluation but nevertheless one

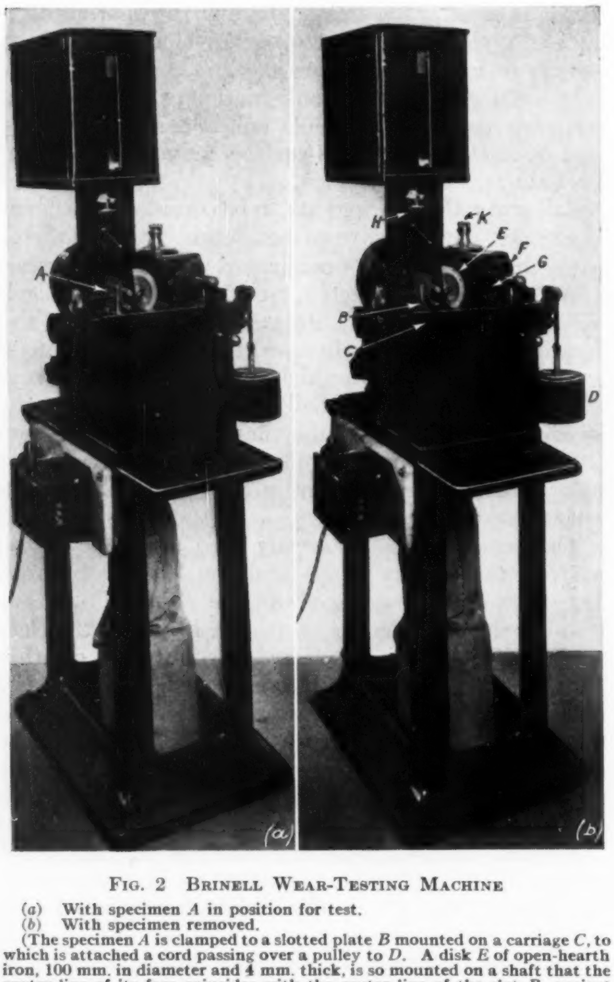


FIG. 2 BRINELL WEAR-TESTING MACHINE

(*a*) With specimen *A* in position for test.
(*b*) With specimen removed.

(The specimen *A* is clamped to a slotted plate *B* mounted on a carriage *C*, to which is attached a cord passing over a pulley to *D*. A disk *E* of open-hearth iron, 100 mm. in diameter and 4 mm. thick, is so mounted on a shaft that the center line of its face coincides with the center line of the slot *B*, against which the specimen is clamped. When the cam *F*, working against a stop *G* on the slide, is turned to the proper position, the carriage *C*, mounted on ball bearings, moves to the right until the specimen rests against the disk *E*, the pressure between the two being determined by the weights attached to the end of the slide. A hopper *H* mounted above the slotted plate is filled with sand fed into it from the receptacle placed above. During test a continuous stream of standardized sand is passed between the specimen *A* and the disk *E*. The disk has a speed of 45 r.p.m., and the linear travel of a point on its circumference can be adjusted by a graduated wheel and lock nut *K* on top of the machine.)

which is possibly rather unique. This is that the electrolytically deposited metal has a surface which appears to be very little inclined toward "galling" or "seizing" against another metal surface. For example, chromium-plated tools for metal spinning rarely if ever seize on the work in the spinning lathe, even in the ha nds of a novice

Nitride hardening is another relatively new method of surface hardening, similar to carburizing in that the hardening agent—nitrogen in this case—is caused to diffuse at an elevated temperature into the surface layers of the steel being treated. It differs from carburizing in that the nitride layer as it cools normally from the temperature of formation has already developed its full hardness and requires no quenching treatment. Nitride surface hardening is at present apparently finding wider and wider fields of application. It enjoys the reputation of being a surface-hardening process which imparts both wear resistance and certain corrosion-resistant properties. Nor is its hardness lost by exposure to temperatures that would very seriously soften carburized cases.

"Overlaying" or surface-layer welding has been used in building up worn manganese-steel parts with similar manganese-steel weld rod, or for putting a layer of an alloy steel on a plain carbon-steel backing. Stellite, one of the super-hard alloys, has been welded to the surfaces of iron and steel backs, producing surfaces of notable wear resistance.

A few so-called super-hard alloys find certain uses for combating wear. Stellite, already mentioned as one of the materials used in "overlay" welding, is an extremely hard alloy of cobalt, chromium, and tungsten that retains much of its room-temperature hardness even at a red heat. In addition to its use in overlays, it finds application as a high-speed turning tool.

The most recent developments in the field of super-hard alloys are the production and applications of sintered tungsten carbide and tantalum carbide cutting tools and wire- and tube-drawing dies. Alloys of this type have a scratch hardness between that of the sapphire and the diamond, an indentation hardness of 1200 to 1600 Brinell, or possibly even higher; retain much of this hardness at red heats; permit almost unbelievable feeds and depths of cut in lathe turning; and serve as wire-drawing dies both at room temperatures and at elevated temperatures. At room temperatures they have shown startlingly greater resistance to wear than the best previously known metal dies.

V—EVALUATION OF WEAR RESISTANCE BY LABORATORY TESTS

It thus appears that the wear of metals is probably brought about by mechanisms more or less complicated and varying from case to case, depending on the type of service involved; that wearing of metals is encountered on every hand in all types of activities and engineering service; and that there are a number of methods and materials available for use in combating and reducing wear.

It only remains to consider the methods available for quantitatively measuring the wear resistance of metals, and the possibility of predicting their relative wear in service.

Many of the authors of recent papers dealing with the wear of metals have called attention to the fact that the rate of wear of a given metal is not alone a property

of the metal itself but equally, or possibly chiefly, reflects various factors in the conditions of service. That is, there can be no single and universal standard test for wear resistance. The metallurgist interested in the wear of metals must analyze, to the best of his ability, the factors involved in any particular service, and from this analysis he must select or develop a laboratory wear test which shall simulate, as closely as possible, the service conditions he is considering.

For a number of years one of the major lines of research of the metallurgy division of the National Bureau of Standards has been studies of the wear resistance of metals. In the pursuit of such studies a frequently used apparatus for determining wear has been the Amsler machine.[4,5] (Fig. 1.) With this machine it is possible to produce metal-to-metal wear under pure sliding friction, under pure rolling friction, or under combined sliding and rolling friction. Tests of wear can also be carried out under various pressures, with or without lubrication, at normal room temperature or at elevated temperature, and in atmospheres of controlled composition. Under all conditions the frictional energy losses between the wearing specimens can be determined. This single machine is thus a rather versatile apparatus. Wear of the test specimens is accomplished in the Amsler machine by causing two metal disks in contact with each other to revolve in the same direction either at two different speeds, so that there is slip between the metal surfaces, or at the same speed so that there is purely rolling friction. As a measure of wear, the loss in weight of the specimen is compared with the number of revolutions of the disk or the energy expended as friction.

The Brinell wear-testing machine (Fig. 2)[6,7] has been used in the work at the Bureau of Standards in studying abrasive wear. This machine functions by pressing a sheet or plate of the metal being tested against the edge of a rotating disk of soft iron while a fine stream of abrasive (sand) is allowed to fall on the point of contact of sheet and disk. The depth of the slot worn in the test piece or the loss in weight of the test piece under fixed conditions of test is the measure of wear.

Such machines as the Amsler and the Brinell can be used most efficiently in the study of the relative wear resistance of metals under a limited number of definite and controlled factors. But the translation of results obtained with such machines into quantitative terms of probable service life is another matter. In fact, it is usually quite impossible. When predictions as to probable service life are desired, it is necessary to approach the problem in one of the following two ways: (1) Attempt to devise a single machine or testing apparatus which shall combine the recognizable factors from the particular type of service in view; or (2) separate as completely as possible the factors involved and determine how the materials under test behave when subjected separately to these factors.

Illustrative of the design of a machine which shall involve as nearly as possible the actual service conditions of some particular article whose wear resistance is in question, is the machine designed at the Bureau of Standards for the express purpose of studying the wear resistance of plug gages.[8] This machine is constructed to move a cylindrical test specimen (the gage) vertically in a split ring. Provisions are made for adjusting the pressure of the split ring against the moving

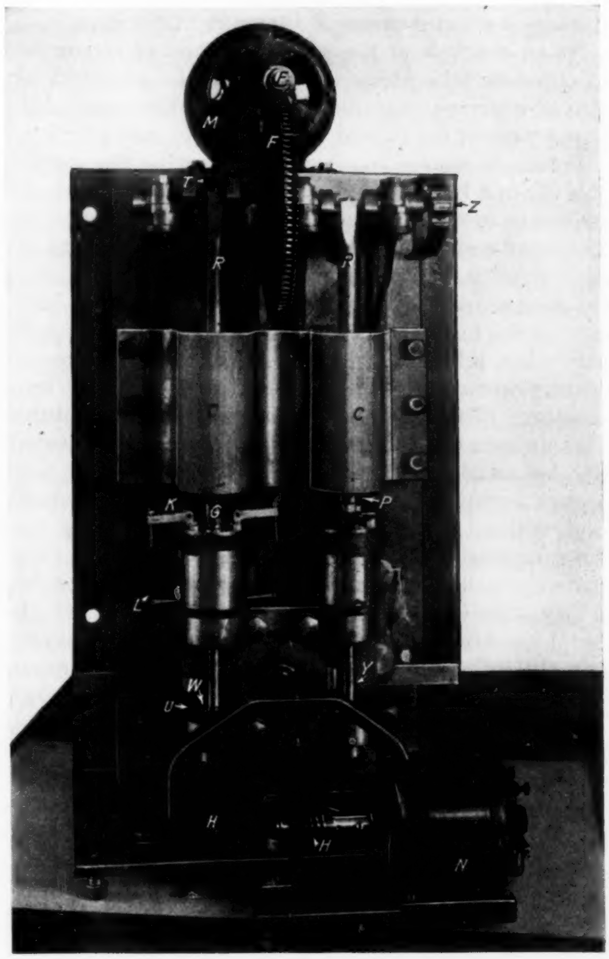


Fig. 3 Gage Wear-Testing Machine

(The gage G is moved vertically in a split ring by means of a piston P sliding in the cylinder C. The piston, which is driven by a motor M through reduction gears F, a connecting rod R, and a crankshaft T, is threaded at its lower end to provide means of attaching the test gage G. The motor N furnishes power which is transmitted through reduction gears H, sprocket wheel W, and chain U, to rotate the split rings. The contact pressure between the gage and the split ring is obtained by springs L acting through the lever arms K. The holder for the split rings is in the form of a cup which holds the cooling liquid. The cups are mounted on a carriage Y, which can be lowered for inserting and removing test gages. A counter Z records the number of gagings.)

[4] H. J. French, S. J. Rosenberg, W. LeC. Harbaugh, and H. C. Cross, "Wear and Mechanical Properties of Railroad Bearing Bronzes at Different Temperatures," B. S. Research Paper No. 13 (1928).

[5] F. P. Hitchcock, "A Universal and Practical Machine, Etc.," *Testing*, vol. 1 (1924), p. 147.

[6] H. A. Holz, "Brinell's Researches on Iron, Steel, and Other Materials to Wear," *Testing*, vol. 1 (1924), p. 104.

[7] S. J. Rosenberg, "The Resistance of Steel to Abrasion by Sand," B. S. Research Paper No. 214 (1930).

[8] H. J. French and H. K. Herschman, "Wear of Steels With Particular Reference to Plug Gages," Trans. Am. Soc. Steel Treating, vol. 44 (1927), p. 457.

test specimen and for the horizontal rotation of the split ring about the specimen. The alternate insertion and removal of a plug gage from the hole being gaged and the "wringing" action often characteristic of the use of such gages are thus simulated. It is also possible to carry out these same wearing operations in the presence of abrasives. The measure of wear with this apparatus is the decrease in weight or in diameter of the gage, while the wear resistance of the gage is taken as the number of "gagings," or insertions in the split ring, necessary to cause a given decrease in diameter of the gage.

As an example of the second method of attempting to correlate laboratory testing with the practical service of wear-resisting metals may be taken some of the recent work of the Bureau in the field of bearing bronzes.

Foremost among the factors influencing the serviceable life of a bronze bearing is placed quite naturally its resistance to metal-to-metal wear under sliding friction. The wear resistance may be studied in the laboratory with the Amsler machine, and frequently this study has been of metal-to-metal wear in the absence of lubricant on the basis that wear of the bearing is appreciable only when lubrication is inefficient or fails. A bronze bearing operates for the greater part of its life at temperatures distinctly above atmospheric temperatures. Therefore tests at elevated temperature are indicated. Besides actual wear resistance, a bronze bearing must possess compressive strength to sustain its working load without plastic deformation. This means that the compressive strength of the alloy within the range of its operating temperatures is a factor in its serviceability. And when the load-carrying ability of the metal has been determined, there comes into the question the influence of pressures within this determined range on the wear resistance. Additional determinations of wear under varying pressures are required. If the bearing bronze is to be used under conditions involving the necessity of resistance to shock, impact tests over the designated temperature range are necessary. In the work of the Bureau on bearing metals, both single-blow and repeated-pounding impact tests are carried out at normal and at elevated temperatures. Temperature has a marked influence on many of the properties of the bearing bronze. It therefore becomes essential to consider, together with the properties thus far enumerated, the coefficient of friction between the bearing bronze and the rotating or reciprocating member it supports. The greater the coefficient of friction, the more marked a rise in temperature of the bearing is to be anticipated. The friction coefficient as determined by the Amsler machine is therefore a factor not to be overlooked.

All of these factors are considered, and the type of test indicated by each is included in the investigations on bearing metals carried out at the Bureau of Standards. The evaluation of a bearing-metal alloy must be based on an attempt to derive a weighted average or a quality factor from these varied tests. At the best it is difficult to translate laboratory data on the wear of metals into predictions of wear resistance in service.

VI—Coordinated Wear Research

The formation of a Wear Research Committee has been considered by groups of both The American Society of Mechanical Engineers and the American Society for Testing Materials. The preparation of this paper was suggested as means of "detonating" discussion of such a proposal.

There can be little question of the breadth of the field and the importance of the wear of materials. Whether there are definite phases of the subject that could be better handled if some cooperative and coordinating group of interested workers were established is a matter for consideration and discussion. The possible advantages will have to be weighed against all that is implied in the words "One more committee!" which will certainly be the immediate comment of many, be they ever so interested in the problems of wear.

The Comparison of Steam Turbines

THE term "efficiency ratio" has, indeed, lost so much of its definiteness, and therefore of its value, that the difficulty of maintaining the underlying idea in any useful manner has driven engineers back to fundamentals. Instead of taking as their criterion the performance of a perfect turbine, as limited by the Second Law of Thermodynamics—for this is really at the basis of the notion of efficiency ratio—they have returned to the axiom stated in the First Law. According to the latter and to the accepted values of units, a kilowatt-hour is the exact equivalent of 3412 B.t.u. Hence a perfect turbine might be regarded as one which would consume no more than this amount of heat for every kilowatt-hour it produced. Actual turbines could thus be compared with perfection, and with each other by stating their heat consumptions per unit of useful work, regardless altogether of their steam conditions, heat cycles, or anything else. The method has the obvious disadvantage of setting up a standard of efficiency far too high to be even theoretically obtainable, owing to the neglect of the restrictions upon heat conversion which are imposed by the Second Law. It does, however, restore one of the practical features of the old method of measuring efficiency by means of steam consumption, for it enables a very good idea to be obtained of the amount of coal required to produce the power by means of the plant in question.

In spite of the drawback of holding up as an ideal a standard of efficiency which must be theoretically unattainable until condensers can work at the absolute zero of temperature—when, it may be noted, every perfect turbine would have the same efficiency, regardless of its initial steam conditions—the method of comparing turbines on the basis of their heat consumptions is coming more and more into use. On the Continent heat consumptions rather than steam consumptions have to be guaranteed in the contracts for all important plants.—*The Engineer*, June 5, 1931, p. 630.

1930 Earnings of Mechanical Engineers[1]

Figures From 9199 Mechanical Engineers Indicate That Half of the Mechanical Engineers in This Country Who Were at the Age of Maximum Earning Power in 1930, Earned a Professional Income of $7600 or Over. A Quarter of Those Who Were at This Age Earned Over $12,500. A Tenth Earned More Than $25,000

THE accompanying charts and tables give in considerable detail the 1930 earnings of mechanical engineers.[2] In reading these figures it is important to bear the following points in mind:

1 *The figures are based on 1930 earnings.* At that time the effects of the present depression had not seriously reached professional salaries, and few salary cuts had been made.

2 *The figures refer to professional incomes only.* Consequently they can only be compared with other figures which clearly refer *exclusively* to *professional* incomes and do not, as is often the case with figures of incomes, include incomes from investments and other sources.

3 *The figures do not refer to average, but to "median" earnings.*[3] Median earnings give a truer picture than average earnings, because the exceptional salaries of the few men at the top inflate the mathematical average far above the earnings of the typical man; while the median, which is determined by position in the earning scale, not by averaging of salaries, is uninfluenced by exceptional top salaries. Average earnings are usually much more than median earnings. For example, the average of 1930 professional earnings of mechanical engineers between the ages of 53 and 58—the age of maximum earning power—was $10,200, which is more than 36 per cent greater than the median earnings at those ages, which was $7600.

4 *Throughout this report, earnings were figured for groups based on years after graduation, and on comparable ages.* By using groups instead of individual years we were able to get much more reliable figures because of the larger numbers in every group from which the medians were taken. In a few classifications there were not sufficient numbers of men reporting to make a reliable report at all ages, and in these cases the lines are stopped at the point of the last reliable figures.

We believe these figures to be the most reliable that have been obtained as to engineering earnings. They are based on replies from over 50 per cent of the membership of The American Society of Mechanical Engineers in the United States on questionnaires where identification was impossible.

How Earnings Vary—U. S. as a Whole

Fig. 1 indicates the 1930 professional earnings of mechanical engineers in the United States as a whole. In addition to median earnings, it indicates earnings at four other significant positions—at the upper boundaries of the *lowest 10 per cent* and of the *lowest 25 per cent,* and at the lower boundaries of the *highest 25 per cent* and of the *highest 10 per cent.*

A comparison of earnings at these different positions indicates both the extent to which earnings of exceptional men soar above the average as they grow older, and the fact that among the men higher in the salary scale, wages continue to increase with years until a considerably greater age than among lower earners. Thus, the maximum earnings at the upper boundary of men in the *lowest 10 per cent* are earned by men between 43 and 47 years old: the maximum earnings at the lower boundary of the *top 10 per cent* are earned by men from 58 to 62 years old. From the start, however, although the increase in dollars per year may be more, earnings at all salary boundaries generally increase at a slower ratio each successive year as men grow older, with a significant turning point in rate of increase between 35 and 40 years of age, as well as at the maximum. Table 1, which shows the average rate of increase per annum, indicates clearly the period of rapid increase, the period of slow increase, and the period of decline at different earning levels.

TABLE 1 AVERAGE PERCENTAGE OF SALARY INCREASE PER ANNUM

	Period of rapid increase				Period of slow increase			
Between the ages of	23½–26	26–30	30–35	35–40	40–45	45–50	50–55	55–60
Bottom of **highest** 10 per cent	18.5% p.a.	10.8% p.a.	8.8% p.a.	8.1% p.a.	3.6% p.a.	2.3% p.a.	2.2% p.a.	4.6% p.a.
Bottom of **highest** 25 per cent	14.7	9.2	7.2	7.4	2.1	1.9	2.5	—0.6
Median	**12.1**	**7.5**	**6.0**	**4.7**	**1.7**	**1.2**	**1.9**	**—0.2**
Top of **lowest** 25 per cent	10.8	5.7	4.6	2.6	2.2	1.1	—0.2	—0.4
Top of **lowest** 10 per cent	10.6	5.7	4.3	0.8	2.6	—0.9	—1.0	0.1
	Period of rapid increase			Period of slow increase		Period of decline		

[1] Prepared by the Committee on the Economic Status of the Engineer, of The American Society of Mechanical Engineers. The survey and the preparation of the report were directed by Prof. Elliott Dunlap Smith of Yale University. The statistical computation was directed by Prof. Hudson B. Hastings of Yale University.

[2] More detailed data will be given in subsequent issues.

[3] To get the "median" earnings in any classification, the salaries of all the engineers in the classification are arranged in a column in order of size. The total number of entries in the classification is then counted, and the salary of the man who comes in the middle of all the men in the classification is then taken as the "median" of the classification.

Not only do salaries increase more rapidly in youth, but the rate of spread between the salaries of high-paid and low-paid men is greatest in early years. The percentage by which higher and lower boundaries vary from the median at characteristic ages is shown in

TABLE 2 VARIATION OF WAGE BOUNDARIES FROM MEDIAN

Between the ages of:	23–24 years	38–42 years	57–62 years
	Per cent above median		
Bottom of *highest* 10 per cent..	+30	+124	+233
Bottom of *highest* 25 per cent..	+12	+ 52	+ 61
Median....................	0	0	0
Top of *lowest* 25 per cent......	—10	—33	—41
Top of *lowest* 10 per cent......	—25	—52	—56

Table 2. It indicates that, except for earnings in

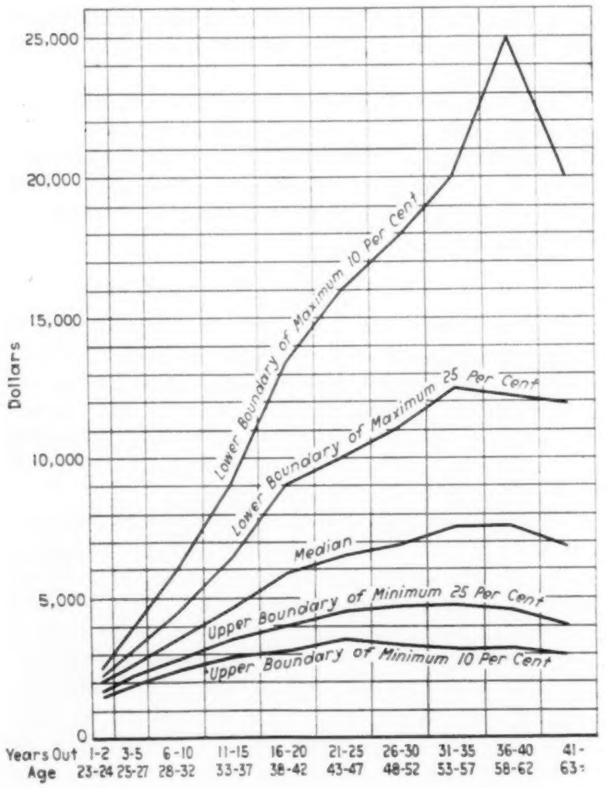


FIG. 1 1930 EARNINGS OF MECHANICAL ENGINEERS—U. S. AS A WHOLE

(Exclusive of salaries of teachers and of employees of the Federal Government.)

the upper 10 per cent, the increase in spread between salary boundaries is slow after 40 years of age.

Engineering earnings do not decline seriously with age. Median earnings of men over 63 years old practically equal those of men 48 to 52 years old. The lower boundary of the *top 10 per cent* is as high after 63 years of age as it was from 53 to 57. Even the upper boundary of the *lowest 10 per cent*, where the peak is reached at from 43 to 47 years, does not decline after 63 to substantially less than it was at from 33 to 37.

If median 1930 earnings are considered as the earnings of the typical engineer, and it is assumed that the typical engineer marries at 26 years of age, and has two children at thirty, who grow up and go to college, the balance sheet of earnings and responsibilities on the 1930 basis will be about this: He will have about $2700 to marry on; when his second child is born he will have about $3500 with which to support his wife, his two children, and himself. When he is 45 and his children are entering high school, he will have about $6500 for his family income. At 50, 28 years after he himself was graduated from college, he will have two children in college and earn about $7000 a year. If he gives each child $1000 a year for tuition and expenses, he will have $5000 left to support his wife and himself. At 60, with his children presumably self-supporting, he and his wife will have $7500 a year to spend, but must look forward to a decline in earning power to $6800 after 63.

How Earnings Are Affected by Location

Fig. 2 gives comparative earnings of mechanical engineers in the main geographical areas of the United States. Although only median earnings are shown, an examination of earnings in these geographical areas at both higher and lower salary boundaries indicates that the comparative levels of median earnings in the several geographical areas are roughly typical of all comparative earnings.

The New York Metropolitan district gives the highest median earnings at all ages below 63 but these are not substantially above earnings in the Middle Atlantic states except for men over 40 or the Middle West, except for men over 50. If the cost of living is taken into account there would probably be but little, if any, differential in favor of New York below that age. How much the sharp increase in earnings in New York City for men in the 50's is due to the calling to this city of leading men from other areas, it is impossible to determine.

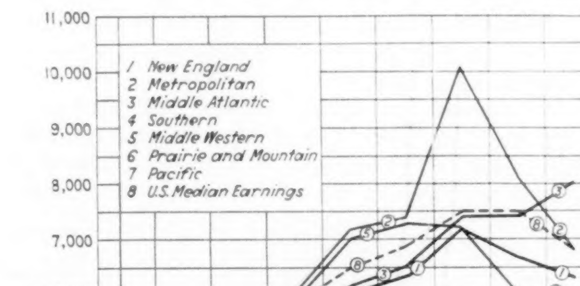


FIG. 2 1930 MEDIAN EARNINGS BY GEOGRAPHICAL AREAS

In the Middle West, median earnings are slightly above the United States median until 50, after which there is a striking decline in earning power. The Middle Atlantic states fall behind the median of the United States at 40, but practically catch up at 55, and are well above the United States median at 65, although at the higher salary boundaries earnings remain low. Between 35 and 55 years of age, New England earnings are approximately $500 less than the median of the United States as a whole. After 60, they are nearly $800 less. In the South young men under 35 earn well, but thereafter median salaries are consistently low, averaging over $1000 below the United States median, but salaries at the higher boundaries are not below the country as a whole, even for men in their forties. In the Prairie and Mountain, and Pacific states earnings are distinctly the lowest at all ages, except for salaries in the Pacific states for men between 38 and 42, who earn a little above the United States median, and salaries of the men in the Prairie and Mountain states between 48 and 52, which equal those of the South.

The numerical distribution of members of the Society in the several geographical areas, together with the maximum median earnings in each area, are shown in Table 3.

TABLE 3 DISTRIBUTION OF MEMBERSHIP

Geographical area	No. of members[1]	Per cent of U. S. membership	Maximum median salary
Metropolitan	4,928	27	$10,000
Middle Atlantic	3,857	22	8,000
Middle West	4,506	25	7,300
New England	2,038	11	7,200
Southern	1,097	6	6,000
Pacific	1,015	6	6,000
Prairie and Mountain	469	3	6,000
Total	17,910	100	

[1] This figure is the total membership of the Society in each area, and does not indicate the number who replied to the questionnaire.

How Earnings Vary With Education

Fig. 3 indicates the effect of education upon earnings. "Engineering B.S." comprises only men who had received a degree of B.S. in engineering from an engineering school of recognized college rank. "Engineering B.S. plus" comprises those men who added to their B.S. degree a year or more of technical graduate work at a recognized engineering college. "Non-graduates" are those men who had completed at least three years of work at a recognized engineering school but did not get their degree. "Sub-collegiate" includes all men whose education comprised a course of study of at least three years in a night school or school of less than college grade. "Non-technical" includes all men whose training is less than "non-graduate" or "sub-collegiate." There were inadequate numbers to give reliable figures as to the earnings of men who had taken college training other than in engineering, or had taken a B.A. degree before going to engineering schools. The number of questionnaires from which the earnings in each of these groups were figured is shown in Table 4.

Technically trained men from recognized engineering colleges command median earnings at approximately a premium of $500 over men with inferior training, from the time they are 25 until they are 35. Above this age they forge rapidly ahead until at 45 they are over $1000 ahead of men without technical training,

TABLE 4 DISTRIBUTION BY TYPE OF EDUCATION

Type of education	Number of replies	Per cent of total
Engineering B.S. plus	619	8
Engineering B.S.	4,918	63
Non-graduate	492	6
Sub-collegiate	336	4
Non-technical	1,167	15
College B.A. plus Engrg. B.S.	164	2
College B.A.	123	2

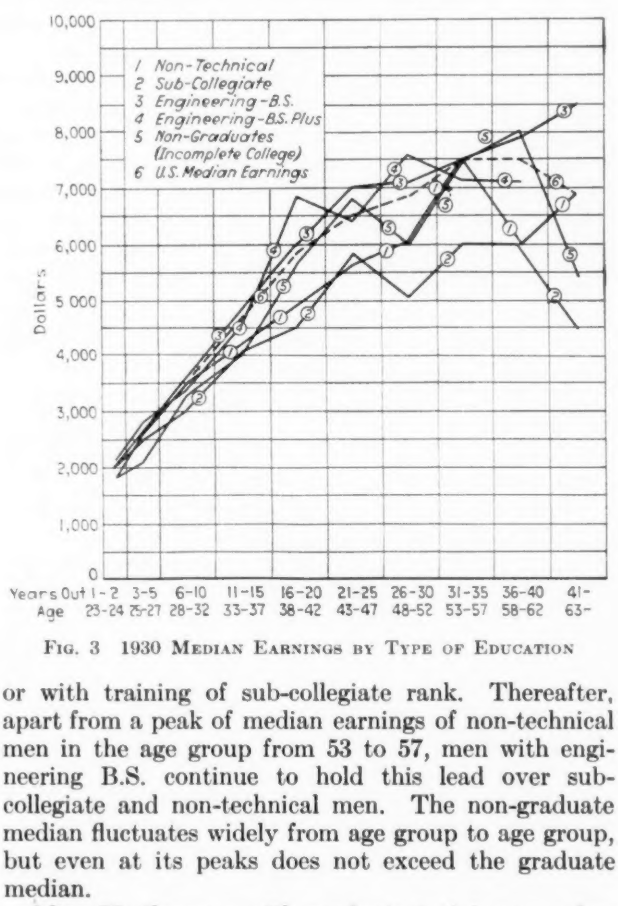


Fig. 3 1930 Median Earnings by Type of Education

or with training of sub-collegiate rank. Thereafter, apart from a peak of median earnings of non-technical men in the age group from 53 to 57, men with engineering B.S. continue to hold this lead over sub-collegiate and non-technical men. The non-graduate median fluctuates widely from age group to age group, but even at its peaks does not exceed the graduate median.

After 55, the men with graduate training earn less than men with standard engineering-school training, possibly due to the fact that they tend to stay in strictly research positions and do not become general executives. At the higher salary boundaries the spread between the earning power of men with graduate training and the higher incomes of men with only their B.S. degrees increases.

The fact that men with training of sub-collegiate rank at almost all ages earn less than men without technical training, may be partly due to the fact that men without technical training are not likely to take out membership in the Society unless they have made a moderate success in engineering, while men with night-school or similar training are more likely to register as engineers regardless of success.

What Engineers Earn in Different Industries

Fig. 4 gives median earnings by industrial classifications. "Chemical manufacturing" includes oil, mining, and metallurgical, as well as strictly chemical industries. "Machinery Manufacturing" includes electrical equipment, automobiles, airplanes, and metal products; while "Power Machinery Manufacturing" includes in addition to stationary power machines, refrigeration, heating, and ventilating equipment. Apart from this, the classifications are largely self-explanatory. The distribution of members who replied, among the various industrial classifications is shown in Table 5. In industries other than those charted, there were insufficient replies to permit of reliable figures.

"Machinery manufacturing" and "chemical" follow closely the United States median. "Consulting," "construction," and "non-metal manufacturing" industries show slightly higher pay for ages up to 50, at which age they come down close to United States median earnings. After 35, median earnings in "power machinery manufacturing" and "public utilities" fall off distinctly, although earnings in these industries at lower wage levels do not decline. By the age of 60, "power machinery" pays almost $2000 below the United States median wage. Figures for public utilities for men over 52 are insufficient to be reliable.

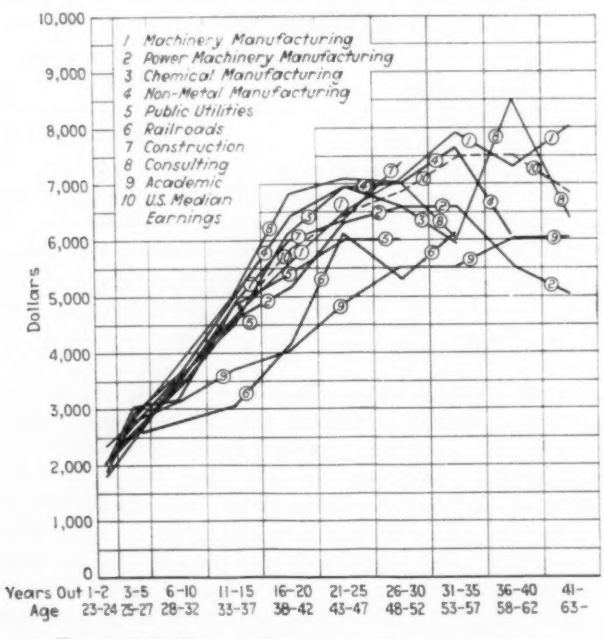


Fig. 4 1930 Median Earnings by Type of Industry

TABLE 5 DISTRIBUTION OF ENGINEERS BY INDUSTRIES

	Number of replies	Per cent of total
Machinery manufacturing	3051	38
Power machinery manufacturing	934	12
Public utilities	776	9
Consulting	755	9
Non-metal industries	648	8
Academic institutions	593	8
Chemical	585	7
Construction	251	3
Railroads	127	2
Financial	91	1
Commercial	74	1

Although the number of returns from railroads is small, the results at all wage boundaries are so consistent as apparently to justify the inference that railroads pay below the median wage almost from the start.

Median academic wages begin to fall below the median of the country as a whole at 28, and by 55 are approximately $2000 below. There is a slight pick-up after this point. The relative deficiency in academic earnings grows increasingly less in the lower wage ranges. The upper boundary of *the lowest 10 per cent* for teaching follows closely that for United States as a whole, although lagging slightly below it at 40 and surpassing it after 50. Although in the higher wage ranges academic earnings are often extensively supplemented by consulting fees, such earnings show a far greater deficiency below industrial earnings there than in the lower wage ranges.

After 55 we have adequate figures on only five industries. "Consulting" and "machinery manufacturing" give the largest earnings. "Non-metal manufacturing" drops off distinctly, but does not reach as low a level as power machinery manufacturing. Meanwhile, academic earnings pass those in "power machinery manufacturing" and equal those in "non-metal manufacturing."

What Engineers Earn on Different Types of Job

Fig. 5 gives comparative median earnings in the various sorts of work in which engineers engage. "Designing" includes all industrial research. "Technical operation" includes all maintenance, inspection, production control, and similar technical work relating to operation. "Consulting" as a type of job includes only actual consultants, and does not include consultant's employees as consulting as an industry does. "General management" includes all men in general executive work from assistant foremen up.

In classifying men by type of work an effort was made to include under each special type of work all the work of that character, regardless of whether the job could also be considered managerial, so that a man would not shift from one of the technical classifications to the general managerial classification merely because he progressed in his work to a position involving executive duties. For example, all men primarily concerned with industrial research or with the development of engineering design, even though they held such executive positions as chief engineer, or vice-president, were classified in the "designing" group. Similarly, all men primarily responsible for technical operation, including plant engineers and higher executives, were put in the "technical operating" group, regardless of the executive nature of their position. All persons directly related to sales or buying, from salesmen and buyers up through general purchasing agents, district managers, to vice-presidents in charge of sales and merchandising, were included in the selling and buying group. No one was put in the general management group unless his job was not only of a managerial character, but did not fall into any one of the special types of engineering work.

Table 6 indicates the number of men in each of these job groups who replied to the questionnaire.

TABLE 6 DISTRIBUTION OF ENGINEERS BY JOB GROUPS

Job group	No. of replies	Per cent of total
Designing	2,882	35
Technical operation	1,534	19
General management	1,345	17
Selling and buying	961	12
Academic	593	7
Consulting	320	4
Clerical	213	3
Owners or partners	138	2
Financial	91	1

Teaching and those jobs where technical skill is the primary qualification ("technical operation" and "designing") are paid on about the same scale and throughout distinctly less than the median of the United States as a whole. Teaching shows a somewhat lower earning power than technical work between the ages of 30 and 40, and a distinctly higher earning power above 55. The median for buying and selling follows closely the median of the United States as a whole until the age of 45. After this age it falls distinctly below. Work which involves primarily either the capacity to handle independent businesses and to meet people as consultants, or the capacity to manage men and affairs as "general managers," is consistently well paid, general management especially soaring in earning power.

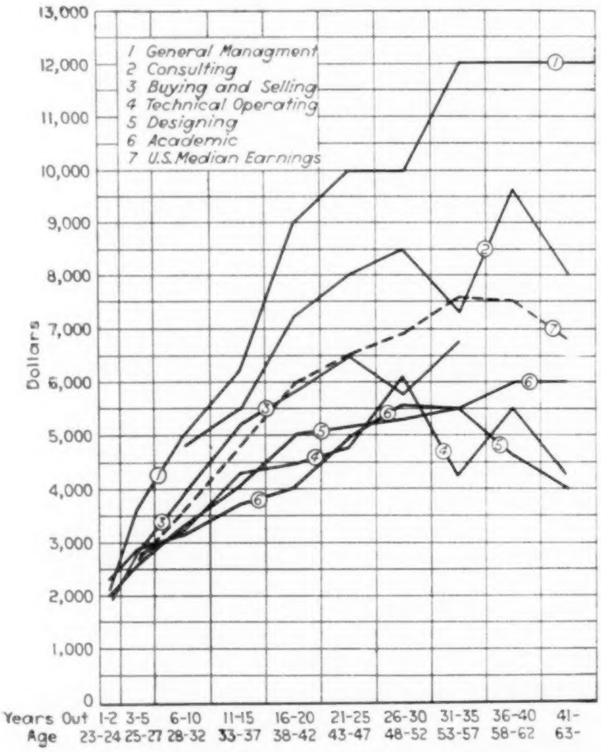


FIG. 5 1930 MEDIAN EARNINGS BY TYPE OF OCCUPATION[4]

[4] The curves in Fig. 5 vary somewhat from those in the preliminary report, as they are based on a careful reclassification and recomputation of the original returns.

The relations between the median earnings of the different types of jobs also hold at other salary ranges, the differences becoming more emphatic, however, as higher wage levels are reached. This is illustrated by the salary boundaries of men in the "designing" and in the "general management" classifications at typical ages, and by the percentage by which managerial earnings exceed designers' earnings, shown in Table 7.

Managers, consultants, and teachers, show little falling off in old age, but designers, research men, and technical operating men, show an age drop after 50.

Not only is there this striking difference between general management and consulting on the one hand, and design, research, and technical operation on the other, but there is a significant difference in earnings, especially among designers and research men, between those engineers doing technical work who have managerial duties and those who do not. The extent of this difference at typical ages is shown in Table 8 both for men in the design and research, and in the technical-operation classifications.

TABLE 8 RELATIVE EARNINGS OF NON-MANAGERIAL AND MANAGERIAL TECHNICIANS

	Research and Design			Technical Operation		
Age	Non-Managerial	Managerial	Excess, per cent	Non-Managerial	Managerial	Excess, per cent
30	$3200	$3600	12	$3100	$3600	16
40	4500	5800	29	4500	4400	2
50	5000	6700	34	5400	6100	13
60	3900	5700	46	4800	5600	17

A broader indication of the influence of the possession of managerial ability upon the progress of engineers in their careers is given by Fig. 6. There all men doing executive work in industry are grouped in a single classification as "industrial managers," regardless of whether their executive duties relate to general management, design or research management, or to management in the field of technical operation. Similarly all technicians whose work does not involve substantial executive responsibilities are grouped in one classification as "industrial technicians," regardless of whether they are designers or do technical-operation work. The median earnings of "industrial managers" correspond with striking closeness to those of consultants

TABLE 7 RELATIVE EARNINGS OF "DESIGNERS" AND "GENERAL MANAGERS"

Age		Bottom of *highest* 10%	Management excess %	Bottom of *highest* 25%	Management excess %	**Median**	Management excess %	Top of *lowest* 25%	Management excess %	Top of *lowest* 10%	Management excess %
30	Desg.	$5,000		$4,000		**$3,300**		$2,800		$2,400	
	Mgt.	9,200	84	7,100	77	**5,000**	**52**	3,600	29	3,000	25
40	Desg.	10,000		7,000		**5,000**		3,600		3,000	
	Mgt.	18,100	81	12,100	73	**9,000**	**80**	6,000	67	4,300	43
50	Desg.	11,000		7,600		**5,300**		3,900		3,000	
	Mgt.	25,000	127	16,000	110	**10,000**	**89**	6,100	56	5,000	67
65	Desg.	11,000		6,200		**4,000**		3,300		2,700	
	Mgt.	40,000	264	17,500	183	**12,000**	**200**	7,500	127	4,300	59
Maximum	Desg.	12,000		8,500		**5,500**		4,000		3,300	
	Mgt.	40,000	233	23,000	171	**12,000**	**118**	8,600	115	6,000	82
Age at Maximum	Desg.	55		55		**55**		45		45	
	Mgt.	65		60		**55-63**		55		55	

at almost all ages. "Industrial technicians" earn about the same as academic men until 42, after which age the teachers earn substantially more. Managerial medians surpass non-managerial medians throughout, being approximately 25 per cent more at 30 years of age and increasing consistently with age until they are more than 100 per cent more at 55 years of age and above. Above the age of 32 there are 2055 mechanical engineers in the "industrial management" classification as against

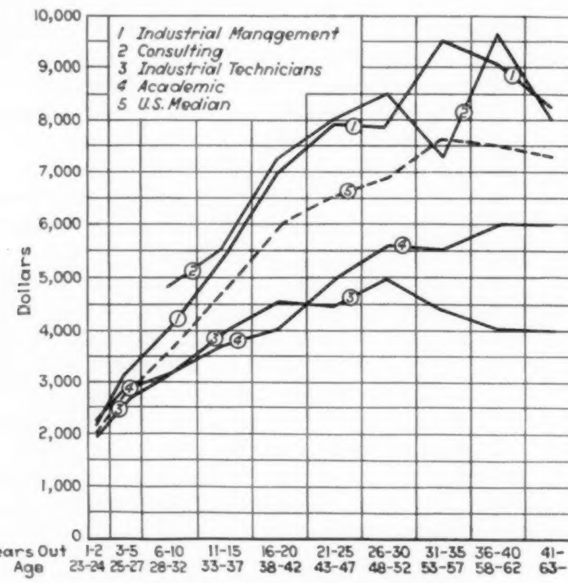


Fig. 6 Influence of Managerial Ability

1119 in the "industrial technicians" group—83 per cent more. The opportunities for engineers to acquire managerial positions is thus large.

A comparison of the charts for type of job with those of different industries, indicates that while academic institutions pay less than almost any other employer, the earnings of teachers compare favorably with earnings in the technical branches of engineering. It also indicates that the differences between types of industries are relatively small compared with the differences between types of work. Apart from teaching and railroads, it makes relatively little difference what industry a man goes into. If, however, he cannot combine with his technical skill a generous degree of capacity to deal with and manage men and affairs, either as a manager of some branch of work in an industrial organization or as a man managing his own business as a consultant, his chances of earning a high salary are reduced. Not only will he fail of the opportunity of promotion to the top positions, which are almost invariably positions involving primarily a capacity for general management, but from the age of 25 on he will find himself in a distinctly lower-paid type of work. Even in the technical-operation and especially the designing fields the highest salaries are received by men whose work involves executive responsibilities.

Regardless of whether the grouping is by type of technical function as in Fig. 5, or by managerial and non-managerial responsibilities as in Fig. 6, the differences between managerial and consulting earnings, and all others, is so great as to suggest the importance to young men well trained in engineering, of seeking to add to their engineering abilities some capacity for dealing with people or for managing organizations or businesses.

Summary

The outstanding points about earnings in 1930, brought out by the survey, are:

1 That the maximum professional income of the typical mechanical engineer is **$7600.**

2 That the age of maximum earning power of the typical mechanical engineer is 55, earning power ordinarily not declining seriously with age even in the 60's.

3 That the differences in earning power between high-paid men and men in the middle salary ranges are strikingly great, the lower boundary of *the highest 10 per cent* at its maximum being 233 per cent higher than the maximum of median earnings.

4 That salaries are distinctly lowest in the Far West, and that the New York Metropolitan district has much the largest percentage of high-paid men above the age of 50.

5 That a good education is worth while.

6 That apart from railroads and academic institutions, the differences between industries as regards salary opportunities are not great at most ages.

7 That the differences in earning power between men whose work is exclusively technical and those who combine with their technical ability the capacity to handle independent businesses or to manage men or affairs, are great—so great as to indicate the importance of most engineers' seeking to develop themselves in this respect, and of engineering schools' bending their curricula somewhat toward this end.

Committee on the Economic Status of the Engineer

Conrad N. Lauer, *Chairman*

C. F. Hirshfeld
Dexter S. Kimball
H. B. Oatley
W. A. Starrett
H. L. Whittemore
W. E. Wickenden
James M. Todd
C. E. Davies, *Exec. Secretary, A.S.M.E.*

I commend to you an examination of what your obligations are in this modern world and a continuing study of how you intend to perform them. Democracies will fail unless you do. The political liberty of the individual will be diminished from necessity unless you do. Dictators will arise to perform your responsibilities, and having performed them, they will take their full toll from your liberties. Our colleges are in default in this great field of research and instruction. No diplomas should be granted until men and women know something more about the area of their obligations in life and something more about their duty in their performance.—Owen D. Young to the graduating class of St. Lawrence University.

Distribution of Natural Gas in the United States by Long-Distance Pipe Lines

First Utilization of Natural Gas—Discoveries in the West and Southwest—Development of Long-Distance Pipe-Line Transportation—Pipe-Line Costs and Revenues—Overcoming Difficulties Due to Fluctuating Demand—Recovery of Gasoline From Wet Gas—Projected Pipe-Line Service to the Atlantic Seaboard

By H. R. MOORHOUSE,[1] CLEVELAND, OHIO

DEVELOPMENTS in steel pipe which have made possible within the last few years the long-distance transportation of natural gas by pipe lines, have revolutionized an industry which seemed, but a few years ago, to have passed its peak and to be destined to a long period of decline.

Although new discoveries of gas fields have been made and old fields have been more fully developed, it cannot be said that these discoveries or developments are entirely responsible for the remarkable recent growth of the natural-gas industry, because gas could not be a big business until the sources of supply were connected with the potential markets. These markets are but seldom close to the gas fields. In fact the development of this economical transportation medium has encouraged the development of the sources of supply.

What is generally known as the Appalachian district, of which the main gas areas are in Kentucky, West Virginia, Pennsylvania, and Ohio, lies in a part of the country in which there are urban districts providing markets available by the use of fairly short pipe lines. Ten years ago the output of gas from these fields was stationary or diminishing, and while great quantities of gas were being discovered in the West and Southwest, these areas were so far from any quantity markets that such part of the gas as could not be used in the field was allowed to go to waste. Even those expert in the gas business thought that 1922 marked about the peak of the natural-gas business.

Improvements in pipe making stepped in, however, and there has been a dramatic change. With the possibility of long-distance pipe-line transportation the natural gas which was going to waste assumed a potential value, new explorations were made, and a period of great expansion commenced.

How great this expansion is can be realized by the statement that in the early months of the present year pipe-line projects calling for the laying of 9586 miles of natural-gas pipe were announced, indicating that by the conclusion of the year all records for pipe-line extensions will probably have been broken.

One pipe line 1000 miles in length, connecting the Panhandle of Texas with the city of Chicago, is rapidly being completed. Natural-gas pipe-line construction so far planned for 1931 will call for the expenditure of approximately $450,000,000.

Natural Gas First Utilized a Century Ago

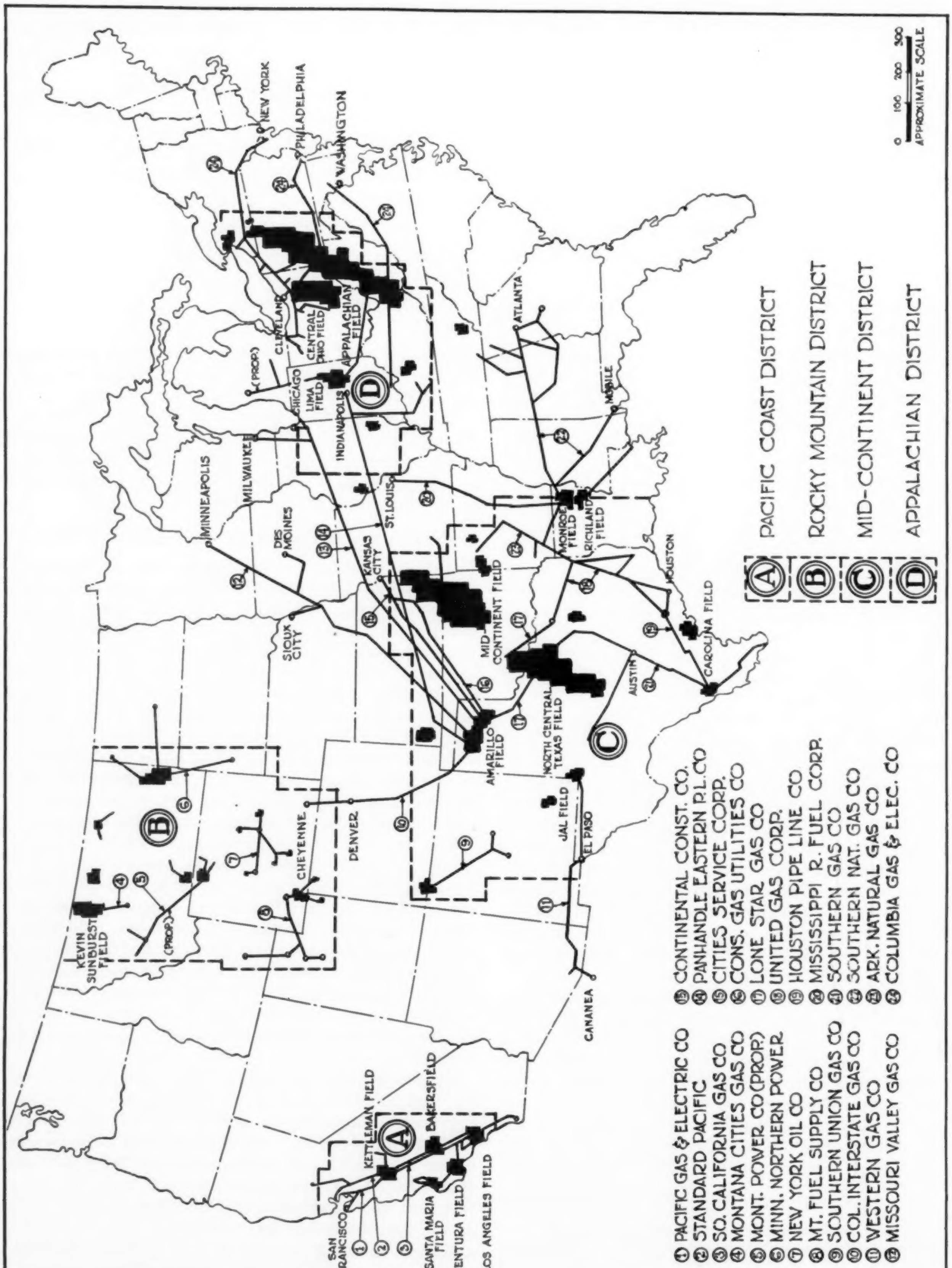
Natural gas as an illuminant and an industrial fuel has been known in the United States for something more than 100 years. The first industrial use, and the first use of any kind, was at McConnellsville, Ohio, in 1820. Early in that year Rufus Stone was drilling for brine from which to make salt, when he accidentally came upon gas. Discouraged by his failure to reach salt he was on the point of abandoning the well as worthless, when Capt. Henry Stull convinced him that the gas could be burned to evaporate brine from other wells in the manufacture of salt. This process proved successful, and continued in use along the Ohio and Muskingum rivers for some years.

The first use of gas for lighting was in Fredonia, N. Y., in 1826. Laying of pipes into the little New York city from wells near by was started two years before, and when the line was completed service was begun with about 100 lights in the town. For many years the principal use of gas was for illumination. In 1865 Fredonia, which had pioneered in gas lighting, saw the organization of the first gas company with the incorporation of the Fredonia Gas, Light & Water Works Company, and the domestic use of gas was begun.

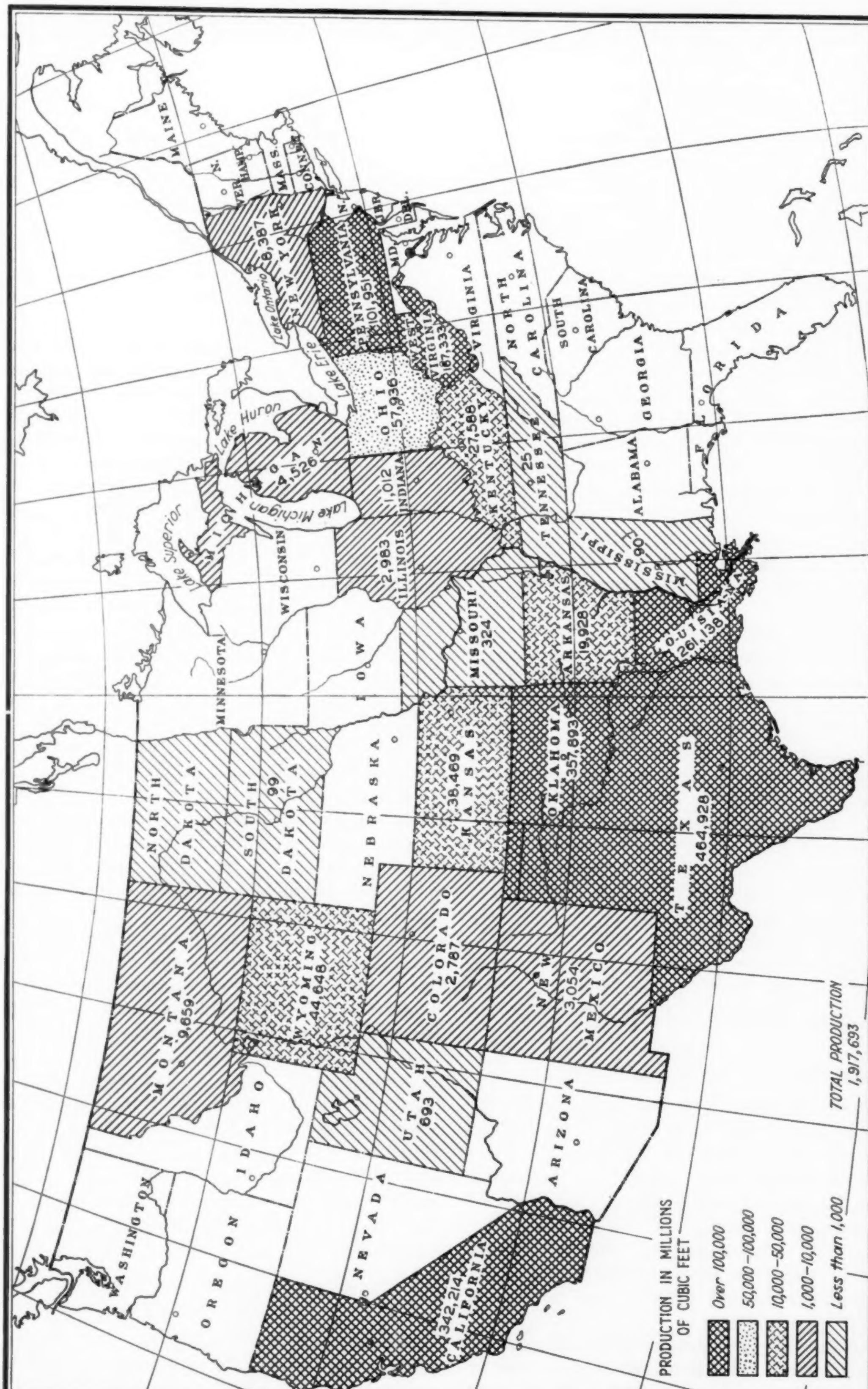
In immediately succeeding years gas was adopted by various communities for lighting and domestic purposes. Titusville, Pa., had a 2-in. line laid from a well five miles north of the town in 1872. Two years earlier an 8-in. line of wooden pipe had been laid into Rochester, N. Y., to provide gas for both light and fuel, but the experiment was not entirely successful, as the gas obtainable there proved a poor illuminant and it was not until gas mantles were perfected that full satisfaction was obtained with all-natural-gas supply.

[1] Industrial Economist, Arthur G. McKee & Company, Engineers and Contractors.

Note: The author desires to acknowledge the valuable assistance and statistical information given by the United States Department of Commerce, Bureau of Mines Division, and the American Gas Association.



Some of the Principal Natural-Gas Pipe Lines in Operation or Under Construction



MAP SHOWING PRODUCTION OF NATURAL GAS IN 1929 BY STATES
(Source: Bureau of Mines, U. S. Department of Commerce.)

After the use of gas for evaporating salt brine no other industrial use of gas for fuel purposes is recorded until 1860, when most of the output of a gas well drilled at Erie, Pa., went to Erie factories. In East Liverpool, Ohio, at about the same time, pottery makers saw the value of gas fuel for the kilns in which they burned their pottery, and generally put it into use. By 1874 the growing iron and steel industry in western Pennsylvania and eastern Ohio began to make use of natural gas as fuel.

The great obstacle to the general use of natural gas either for industrial or domestic purposes was the lack of transportation and distribution facilities. The town which was close to gas wells could manage street lighting and the factory could run its own pipe line, but these individual efforts were naturally overlapping and uneconomical. The logic of the situation brought about the organization of gas-distribution companies. One of the first of these was the Chartiers Valley Gas Company, organized in 1883 by Pittsburgh capitalists to pipe gas from Washington County into the rapidly growing industrial community of Pittsburgh. This company purchased gas from producing wells, leased other wells, and transported to Pittsburgh in its own pipes the gas so obtained for distribution to industrial customers.

In 1874 Edwin C. Bell discovered that some natural gas was "wet," and that gasoline could be recovered from it by compression. It was not until 1903, however, that the first commercial plant to recover casing-head gasoline from natural gas was built. Carbon black was produced from natural gas in 1885 in Gambier, Ohio. For a time these two by-products of natural gas furnished the only use for gas which was too far from marketing outlets to be used otherwise. So from the time of its discovery until about a decade ago the natural-gas industry had a steady but not spectacular growth. Those wells which were near a profitable market or at which plants for the recovery of gasoline or the manufacture of carbon black were erected were successfully operated. In many other places gas not used for field purposes went to waste, or was allowed to escape in the hope that it would bring in oil.

Discoveries in the West and Southwest

Well after the beginning of the present century the western border line of the natural-gas industry was considered to be the vicinity of Kansas City. Gas had been found further west, usually in the course of exploration for oil, but it was disregarded from the commercial standpoint because of the distance from any market. The real center of the natural-gas industry was in the Appalachian district, and many of the shallow wells in that district were decreasing in volume.

In the meantime discoveries were being made in the West and Southwest. The first well in the Monroe field in Louisiana was drilled in 1909, although no important development work was done there until 1917. The first producing well in the Richland field was drilled in 1926. The Monroe-Richland area is now recognized as having probably one of the greatest potential resources of gas of any field in America, but it was not until the last two or three years that markets were provided for the output from both the Monroe and Richland fields through the building of pipe lines to St. Louis, Shreveport, New Orleans, Birmingham, and Atlanta. In California the gas is largely wet, coming from oil fields, and yields a high percentage of natural gasoline. The Texas Panhandle became a small commercial producer about 1920, and has been immensely developed in recent years.

The introduction of steel pipe, with its light weight, great strength, and strong couplings, entirely rewrote the story of natural gas. Transportation, which had been limited to a few miles with the old pipes of heavy cast-iron wall and small inside diameters, became possible over greater and greater distances as the pipe was made lighter and stronger and cheaper by new and improved processes of steel-pipe making.

Almost at once the lead in natural-gas production shifted from West Virginia to the Southwest in no uncertain fashion. This change in leadership resulted not so much from diminished output in the Appalachian fields as from immensely increased output in the Mid-Continent field of the Southwest and the Rocky Mountain and California fields. West Virginia, for instance, produced in 1921 a total of 174,920,000,000 cu. ft. of natural gas, which was 26 per cent of the total for the United States in that year. In 1929 the West Virginia output was 167,333,000,000 cu. ft., a loss of over 4 per cent from 1921, and the West Virginia total was but 9 per cent of the total production of the country. The Mid-Continent, Rocky Mountain, and California fields, on the other hand, have accounted for nearly all of the increased production of natural gas during the same period.

Most of the new gas fields were developed in exploration for oil. Before the development of pipe-line transportation systems there was serious waste, as practically no use could be made of the gas except the field consumption in the operation of oil machinery and for manufacturing carbon black. Both the development of pipe-line transportation and the legislation of the states in which the gas fields are located now operating to put a stop to the wastage. Texas law, for instance, compels provision for utilization of gas encountered in drilling for oil before any further oil development can be made. Similarly the California legislature has passed laws to preserve the gas resources of that state.

Realignment of Industry Through Perfection of Pipe-Line Systems

Indication of the striking expansion of the natural-gas business through the perfection of pipe-line systems and a legitimate effort to develop markets is found in the history of many of the pipe-line and distributing

companies during the last decade. The system of the Cities Service Company supplying Kansas City, Mo., and Kansas City, Kan., for instance, on purely domestic business in 1922 supplied daily an average of 16,200,000 cu. ft. to the two cities. As sources of supply have been made greater, industrial consumers on "shut-off-without-notice" contracts have been added until the company supplied an average of 50,000,000 cu. ft. per day in 1929.

In the six years from 1922 to 1929 there was an entire realignment of the natural-gas-producing business. At the beginning of that period the Appalachian field was the leading source because of the lack of transportation facilities between fields in other parts of the country and of markets for the gas produced in those fields. By the end of the period the Mid-Continent field, comprising gas-producing areas in Arkansas, Kansas, Louisiana, Oklahoma, and Texas, had stepped up to a production of 1,132,357,000,000 cu. ft., which was 59 per cent of the total production of the country, while the Appalachian field produced 363,195,000,000 cu. ft., or 19 per cent of the total. The Rocky Mountain field produced 2.8 per cent of the whole output, the California field nearly 17.8 per cent, and isolated small fields in other states 1.4 per cent. Total production in 1929 amounted to 1,917,693,000,000 cu. ft.

That development of pipe-line systems has hardly more than started is shown by the vast markets which have as yet been untouched by natural gas.

One survey of 90 cities lying between the Missouri River and Detroit before recent pipe-line construction started, showed a total of 2,543,329 consumers of manufactured gas. There are many such areas, particularly along the eastern seaboard, where gas markets are thoroughly developed by the use of the more expensive manufactured gas, which will undoubtedly be served by long-distance pipe lines in the near future.

Although long-distance pipe-line transportation of natural gas is still in the development stage, there is ample evidence that expansion will continue on a vast scale for some years to come. Capital has evinced a willingness to invest in such transportation systems, and such investment seems to be justified. Existent reserves of natural gas on the basis of 50 per cent recovery for long-distance pipe-line transportation from the Texas Panhandle are said to be nearly 4500 trillion cubic feet in the "sweet gas" area, with the possibility of obtaining several more trillion cubic feet.

The Texas Panhandle area appears to be reinforced by sources of supply in Texas and adjoining states which should serve to strengthen the economic position of long-distance transportation. Reserves are being developed in New Mexico, south Texas, the Oklahoma Panhandle, and southwestern Kansas. Most of these reserves are derived from comparatively shallow sands, so it is safe to believe that supplies for more than 35 years at the present rate of exhaustion are available. This period is ample to allow for the amortization of invested capital in much shorter periods than the now known economic life of the pipe lines, without taking into consideration discoveries of reserves about which nothing is now known.

While it may be said that an industrial market for the sale of natural gas exists in every manufacturing center of importance in the United States, careful surveys are imperative before the financing of a new pipe line or the extension of present pipe-line facilities is justified. New pipe lines or extensions should only be built after thorough study and investigation by practical and experienced operators and by engineers and people experienced in the marketing of gas. It is absolutely essential to have assured and well-diversified sales outlets, besides adequate gas reserves and sufficient capital to take care of initial construction costs, plus working capital to defray expenses until the line begins to operate on a profitable basis.

Cost of a Long-Distance Pipe Line and the Estimated Revenue Therefrom

The construction of a large-diameter long-distance pipe line for the transportation of natural gas involves large amounts of capital, but should return revenues which are satisfactory on minimum load and at minimum rates provided the constructed line is economically justified. To illustrate the financial detail of such an enterprise, say, from the Mid-Continent field eastward, the following tables of estimated cost and gross and net revenue on a line over 900 miles long of 24-in. outside-diameter pipe are given.

Estimate of Construction Cost

Preconstruction expense	$ 350,000
919 miles 24-in. main line at $28,500 per mile	26,191,500
Rock and rough country	525,000
River crossings	1,500,000
Meters, regulators, and settings	500,000
Furniture and fixtures, trucks, garage, and mechanical equipment	300,000
	29,366,500
Compressors—113,000 hp. at $125 per hp.	14,125,000
	43,491,500
15 per cent overhead	6,523,700
	$50,015,200

Estimated Revenue

(To provide 12 per cent return on above investment, assuming 70 per cent load factor on line and all gas sold at terminus)

Estimated Annual Gross Revenue		
16,600,000 M.C.F. domestic consumption, at 45 cents		$ 7,470,000
2,165,000 M.C.F. unaccounted for, at 19 cents		411,000
23,350,000 M.C.F. industrial sales, at 17.8 cents (avg.)		4,156,000
Total gross revenue		$12,037,000
Estimated Operating Expense		
Cost of gas—42,157,500 M.C.F. at 6 cents	$2,529,450	
Cost of gas—lost and used, at 6 cents	398,190	
Compressor-station operation—113,000 hp	911,000	
Pipe-line operation	500,150	
Maintenance reserve	500,150	
Management and overhead	460,000	
Taxes (local, etc.)	750,230	
Total expense	$6,049,170	6,049,170
Estimated Net Revenue From Operation		$ 5,987,830

This pipe line, at a working pressure of 425 lb. per sq. in., would have a capacity of 165,000,000 cu. ft. daily, somewhat in excess of the figures used in the table of estimated gross revenue. At 800 lb. per sq. in., which is entirely feasible, the line would have a capacity of 300,000,000 cu. ft. daily, which, with the proper development of markets, would vastly increase the gross revenues.

Considerable savings may be expected to take place in building pipe lines because of new designs being contemplated for large-capacity long-distance transmission lines. The cost of the steel pipe is over 40 per cent of the total cost of the pipe line. Pipe manufacturers today are designing the largest possible diameter to carry a given quantity, being limited only by a practical wall thickness. The use of higher stresses in the pipe will effect considerable savings in the tonnage of steel necessary for the construction of a pipe line.

Methods of Overcoming the Problem of Fluctuating Demand

In the development of the pipe-line industry one deterrent has been the fluctuating demand of domestic users—fluctuating both as to peak demands during the day and as to varying consumption caused by seasonal temperature changes and the consequent fluctuating consumption in domestic heating. This has been met by "shut-off-without-notice" contracts with industrial users, under which industrial concerns could have the benefit of the gas at times when the domestic demand was lowest.

Four developments are possible to overcome this problem of uneven load. They are:

Mixture of natural and manufactured gas
Interconnecting of great pipe-line systems for stand-by purposes
Storage of natural-gas reserves underground
Propane and butane storage.

In many localities companies which distribute gas from by-product coke plants or from coal- or water-gas plants are buying natural gas from the pipe-line companies and selling mixed gas, which has an entirely satisfactory heat content. The tank-storage facilities which have been a part of manufactured-gas plants serve as the equalizers in such cases, and a steady flow of gas may be assured for both domestic and industrial uses.

The trend toward the practice of mixing natural with manufactured gas is shown by the constantly increasing amounts of natural gas being purchased by the makers of manufactured gas. In the 11-year period from 1919 to 1929, companies manufacturing gas increased their purchases of natural gas from an amount equal to 6.8 per cent of their own manufacture in 1919 to 19 per cent in 1929. While in the past there was a tendency to use the natural gas for domestic purposes, reserving the coke-oven gas for industrial uses, the present practice is for coke-oven gas and natural gas to be complementary fuels rather than competitors.

The great pipe lines with their equalizing pressure possibilities are able to smooth out some of the peaks in consumption, and there is every indication that in the near future such reciprocal relations will be established between different large systems that there will be sufficient stand-by reserve to assure a constant pressure against which the local peaks and valleys of demand will make no impression.

The project of storing gas underground in wells from which the natural pressure has gone has been widely discussed and has been successful in some localities, although the danger of loss in such an effort may prevent its wide use if a satisfactory equalizing of load by the interconnecting of nation-wide pipe-line systems can be secured.

Recovery of Gasoline From "Wet" Gas

One of the most interesting features of the natural-gas development has been the accompanying production of natural or casing-head gasoline from the so-called "wet" gas. The gas is treated and stripped of its natural-gasoline content either by compression under lowered temperatures or by absorption with heavier oils or charcoal. At the beginning of 1930 there were 1035 natural-gasoline plants in the United States, with a daily capacity of 10,516,847 gal. The fields of California, Oklahoma, and Texas produce by far the larger part of the wet gas, the daily capacity of natural-gasoline plants in California being 3,658,386 gal., of those in Oklahoma, 3,085,351 gal., and of those in Texas, 2,219,743 gal.

Commercial motor gasoline as sold in the United States contains an average of about 10 per cent of natural gasoline blended with the refined product. Use of a higher percentage is impractical because of the low volatilization temperature, difficulty of carburization, etc., of the natural gasoline.

Natural gasoline, however, contains elements which, when separated, have a distinct value in the gas field. These are butane and propane. At present these are mostly being wasted or burned under boilers at the point of manufacture, but both have a very high heat content, and because they can be liquefied at comparatively low pressures and reasonable temperatures, offer great possibilities for use in supplying markets now out of reach of natural gas, or for the enrichment of either natural or manufactured gas.

Considerable quantities of butane are now being condensed and shipped in drums under pressure for domestic uses where gas is not yet available. Butane distribution and service plants are being put into operation at many points, principally small towns outside the natural-gas areas. The initial cost of a plant to serve 500 customers with 35,000 cu. ft. of butane vapor per day is about $65,000. There are about 60 butane-air plants in operation at the present time and it is estimated that there are 50 more being constructed or are under contract for construction.

This is one method of preparing a market for natural gas before the laying of a main is feasible. Butane vapor has 3447 B.t.u. per cu. ft. at 32 deg. fahr., and propane, 2685.

Were the combination of butane and propane resulting from natural-gasoline recovery in the Mid-Continent field condensed there and placed in a pipe line, a relatively small-diameter line would carry to St. Louis, Chicago, or eastern points a relatively large number of B.t.u. at very low capital cost for pipe line and low operating cost for pumping stations as compared with a natural-gas line of equal B.t.u. capacity. Such gas would require blending with natural or manufactured gas for the enrichment of the latter or dilution with air for direct use, being too high in fuel value to burn direct from the mains. The storing of such liquid gas in pressure tanks available to a city would furnish a large potential supply of gas for peak loads.

One very large manufacturer of natural or casing-head gasoline is building a pipe line to carry that liquid fuel into St. Louis, and it is reported that the same line will be used for butane, and possibly propane. Whether these latter are actually transported or are recovered after the natural gasoline has been delivered, the effect will be the same—the delivery at market of blending stock for commercial gasoline and of the liquid gases, the value of which would probably more than offset the entire cost of transportation of the natural gasoline.

In the brisk competition bound to follow the rapid encroachment of natural gas on fields hitherto occupied exclusively by manufactured gas or coal, we may very likely see the makers of manufactured gas use butane or propane to enrich their product to a B.t.u. content competitive with the richer natural gas.

The growth of the market for liquefied gases shows that, while great progress has been made, business has not yet been developed on a large scale commercially. In 1922 there were 222,641 gal. produced, and this amount increased year by year to a total for 1929 of 9,925,698 gal. It is estimated that there are available daily from refinery gases and natural gases of the country 2,200,000 million B.t.u. of propane and butane. The heating value of this propane and butane would amount to about 66 per cent of the B.t.u. total of all the natural gas used for domestic and industrial uses other than in the oil fields. About 36 per cent of the natural gas consumed in 1929 was for field uses.

Large-Scale Pipe-Line Service to the Atlantic Seaboard Near at Hand

It is quite evident that the introduction of natural gas on a large scale will occur within the next few years along the Atlantic seaboard, with large-pipe-line service to Washington, Baltimore, Philadelphia, New York, and the southern New England states. Whether this gas will come from the Appalachian field as a result of service now being rendered by that field being displaced by gas from the Mid-Continent field, or direct from the Mid-Continent field, is not certain. The Columbia Gas & Electric Company has started construction work on the west end of its 350-mile 20-in. coupled line originating near Pikeville, Ky., and terminating at Rockville, Md.

TWENTY-FOUR-YEAR RECORD OF THE CONSUMPTION OF NATURAL AND MANUFACTURED GAS IN THE UNITED STATES

	Natural Gas		Manufactured Gas	
Year	Consumption in millions of cubic feet	Number of customers	Consumption in millions of cubic feet[1]	Number of customers
1929	1,917,451	5,115,000	416,030	12,139,000
1928	1,568,000	4,366,000	417,457	11,841,000
1927	1,445,400	3,984,000	408,404	11,450,000
1926	1,313,000	3,731,000	401,115	11,047,000
1925	1,188,600	3,508,000	365,300	10,600,000
1924	1,141,500	3,443,000	351,934	10,200,000
1923	1,007,000	3,234,000	346,312	9,800,000
1922	762,500	3,032,000	314,565	9,400,000
1921	662,100	2,652,000	299,114	9,200,000
1920	798,200	2,636,000	298,888	8,837,000
1919	745,900	2,526,000	278,000	8,484,000
1918	721,000	2,525,000	271,600	8,200,000
1917	795,100	2,450,000	264,500	7,900,000
1916	753,200	2,381,000	231,400	7,600,000
1915	628,600	2,213,000	204,300	7,300,000
1914	591,900	2,095,000	198,800	6,980,000
1913	581,900	1,934,000	188,300	6,660,000
1912	563,200	1,637,000	178,200	6,340,000
1911	513,000	1,512,000	159,100	6,020,000
1910	509,200	1,343,000	149,400	5,700,000
1909	480,700	1,241,000	143,100	5,425,000
1908	402,100	1,180,000	138,600	5,150,000
1907	406,200	1,071,000	132,000	4,875,000
1906	388,800	884,000	122,800	4,600,000

[1] In 1918 and earlier years includes sales of natural gas by manufactured gas companies, Source: Bureau of Mines, U.S. Dept. of Commerce, and American Gas Association.

It is in connection with the relationships between the Appalachian and Mid-Continent fields and the markets of the Atlantic seaboard that the problem of underground storage of natural gas is most discussed, the plan being to store in the depleted areas of the Appalachian field gas piped in from the Mid-Continent field. One feature of this storage plan, should it prove feasible, would be the development of a natural-gas inventory, at least as far as the storage quantities were concerned.

Possibility exists also for the provision of ample reserves at terminal points through storage of liquid propane and butane. It seems possible, in fact, that such storage may be provided at cities like Chicago and Duluth. In the case of places that must be located on a single pipe line remote from the source of supply, propane and butane could be stored under pressure in the liquid form in large quantities without loss or deterioration.

It has been estimated that there are over 65,000 miles of natural-gas pipe lines in the United States. It has been estimated that the total capital investment in the gas industry in the United States is over $5,000,000,000. About two-fifths of this is represented by investments in the natural-gas part of the industry. In 1929, 43 per cent of the whole industry's gross revenue was accounted for by natural gas. This fact, considered with the rapidly increasing investment in natural-gas pipe-line systems, shows to what extent natural gas may be expected to dominate the whole industry in the very near future.

Increasing the Durability of Plywood

Results of Tests Showing the Effectiveness of Preservative Treatment in Retarding the Decomposition of the Glue and in Protecting the Wood Against the Attack of Microorganisms

By DON BROUSE,[1] MADISON, WIS.

ORDINARY casein and blood glues may give highly water-resistant plywood joints that will stand considerable exposure to dampness, but these same joints ultimately weaken and fail when exposed continuously to warm, humid conditions. Whether the main cause of such weakening is action of microorganisms or hydrolytic decomposition of the protein of the glue, is unknown. While the weakening is treated here as though it were caused by microorganisms, the possibility of a purely chemical explanation should not be overlooked. In any event the usefulness of plywood could be greatly extended by the finding of a practical means of materially increasing its life under continuous exposure to dampness.

In tests started at the Forest Products Laboratory[2] in December, 1917, it was demonstrated that the durability of plywood, glued with blood glue and submitted to prolonged exposure to high relative humidities, was increased by treatment with such wood preservatives as sodium fluoride and mercuric chloride. In a second series of tests, started in 1920, panels glued with blood glue and subsequently treated with creosote retained a high percentage of their original strength for some four and one-half years (the entire duration of the test period).

Experiments With Glue Films

In an extensive series of experiments started in 1925 it was shown that mold growth on films of casein or blood-albumin glues may be inhibited by adding suitable preservatives to the glue solution itself. Small quantities of some chemicals, even of the strong antiseptics, had little effect in preventing or retarding the growth of molds on the films, and many compounds were ineffective in any concentration. However, certain chemicals, when added in sufficient quantity, were found effective in decreasing the action of mold and increasing the durability of the glue film when it was exposed in moist air. Of the compounds effective in reducing mold action, many so affected the working properties of the glue solution that good joints were difficult or impossible to obtain. Both ineffective compounds and chemicals injurious to the joint-making properties of the glue were eliminated from further consideration. Remaining were three compounds, namely, coal-tar creosote, beta naphthol, and sodium chromate. Twenty parts of creosote or ten parts of beta naphthol to 100 parts by weight of dry glue added to casein glue greatly reduced mold growth on the glue film, and yet the glue was not coagulated and its joint-making properties were not greatly impaired. Ten parts of sodium chromate may be added to blood-albumin glues with the same result.

Experiments With Plywood Joints

Drawing conclusions concerning the behavior of glue in joints from the behavior of the same glue in film form is unsafe. Therefore, after it had been established that certain compounds would inhibit the development of mold on glue films and that some of these compounds could be added to glue without destroying the joint-making properties, it seemed desirable to test their effectiveness further by exposing the treated glued joints to warmth and high humidity. Consequently a num-

TABLE 1 GLUES AND FORMULAS

Glues	Composition of Mix	Parts by weight
A commercial casein	Dry glue	100
	Water	200
Forest Products Laboratory formula 4B (casein)	Casein	100
	Lime	25
	Sodium silicate	70
	Water	325
Forest Products Laboratory paraformaldehyde blood albumin	Blood albumin	100
	Paraformaldehyde	15
	Ammonium hydroxide	5.5
	Water	190

TABLE 2 ADDITIONS TO THE GLUE AND TREATMENTS OF THE SPECIMENS WITH PRESERVATIVES

Glue	Addition to Glue	Treatment of Glued Specimens
Casein glues	20 parts creosote to 100 parts dry casein	None
	10 parts beta naphthol to 100 parts dry casein	None
	20 parts creosote to 100 parts dry casein	Coated with aluminum powder in spar varnish
	10 parts beta naphthol to 100 parts dry casein	Coated with aluminum powder in spar varnish
Both casein and blood[1] glues	None	Treated with creosote
	None	Dipped in asphalt
	None	Treated with beta naphthol in linseed oil
	None	None[2]
Blood glues	10 parts sodium chromate to 100 parts dry blood	None
	10 parts sodium chromate to 100 parts dry blood	Coated with aluminum powder in spar varnish

[1] The blood-albumin glue, as a part of the formula, contains paraformaldehyde, which undoubtedly has a marked effect on the durability of joints.
[2] Controls.

[1] Assistant Engineer, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture, Mr. Brouse received his education at Purdue University and the University of Wisconsin, and holds the degrees of B.S. in Chemical Engineering (Purdue, 1921), M.S. in Chemical Engineering (Wis., 1925), and Chemical Engineer (Purdue, 1927). Since 1923 he has been with the section of Wood Preservation of the Forest Products Laboratory, dividing time between (a) the study of gluing technic and improvement of the durability of plywood, and (b) the study of paint behavior on different species. He is the author or co-author of a number of publications on glues or gluing technic.

[2] The Forest Products Laboratory is maintained at Madison, Wis., in cooperation with the University of Wisconsin.

ber of birch plywood panels were prepared, using glues treated with the effective preservatives. Other panels were glued with glues containing no added preservatives and were cut into test specimens; the specimens were then treated with these same preservatives or were dipped in asphalt. Still others, glued with treated glues, were coated with a water-resistant coating (aluminum powder in spar varnish). The materials used and the methods of treatment are shown in Tables 1 and 2.

With each glue a sufficient number of 3-ply panels (12 by 12 by $^3/_{16}$ in.—all plies of $^1/_{16}$-in. rotary-cut yellow birch veneer) were glued so that there resulted 15 panels for each one of the combinations shown in Table 2. For example, there were 15 panels glued with a commercial casein glue containing 20 parts of creosote to 100 parts of dry casein, 15 panels glued with Forest Products Laboratory formula 4B containing 10 parts of beta naphthol to 100 parts of dry casein, and so on.

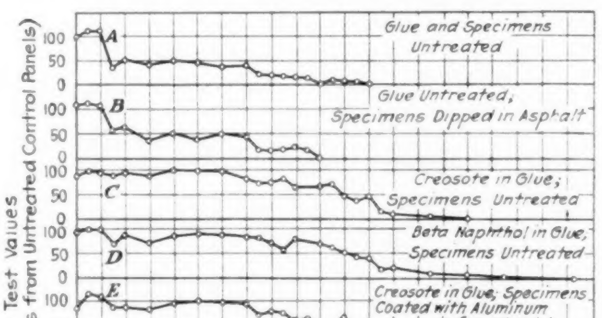


Fig. 1 Effect of Preservatives on the Durability of Glued Joints Made With Casein Glue and Exposed to Relative Humidities Between 95 and 100 Per Cent

Each panel was cut into 30 test specimens,[3] thus producing 450 test specimens for each combination of glue and treatment. Treating operations, if any, were carried out after the panels had been cut into test specimens.

Treatment With Creosote. Designated specimens were immersed in coal-tar creosote, heated to 95 deg. cent., and left for 1 hour, during which time the temperature fell to 60 deg. cent. The absorption averaged 16 lb. of creosote per cubic foot of plywood.

Treatment With Beta Naphthol. A bath was prepared containing 25 per cent (by weight) of beta naphthol in linseed oil. The temperature was raised to 65 deg. cent. to bring the beta naphthol into solution, the designated specimens were immersed, and the temperature was then raised to 95 deg. cent. After this the source of heat was removed and the solution was cooled to 65 deg. cent., at which temperature the specimens were removed to prevent the beta naphthol from precipitating upon them as the solution cooled further to room temperature. The average absorption was about 15 lb. of solution per cubic foot of plywood.

[3] For the form of the specimen and of the testing equipment see U. S. Dept. of Agr. Tech. Bul. No. 205.

Coating With Asphalt. Specimens selected for asphalt treatment were dipped once in a thick asphalt paint, drained, and dried at room temperatures. The weight of the coating averaged 6 grams per square foot of plywood.

Coating With Aluminum Paint. The selected specimens were dipped in a mixture containing 1.5 lb. of aluminum powder per gallon of spar varnish, were then removed, and were dried. The process was repeated once to produce a very heavy coat.

Exposure and Test

After the treatments just outlined, the specimens were seasoned for about two weeks in 60 per cent relative humidity, then one specimen from each panel was tested dry, and another was tested wet after it had soaked for 48 hours in water at room temperature. The average test value dry serves as a basis of comparison for subsequent tests made after exposure of the specimens to high relative humidity. (Figs. 1 and 2.) The remaining specimens were placed in a room where the relative humidity was maintained between 95 and 100 per cent and the temperature at about 80 deg. fahr. Subsequently one specimen from each panel was withdrawn from exposure, at the intervals shown in Figs. 1 and 2, and tested. The 15 test values from the 15 panels were averaged for each glue and each treatment at each of the test intervals to produce the average test values plotted in these figures.

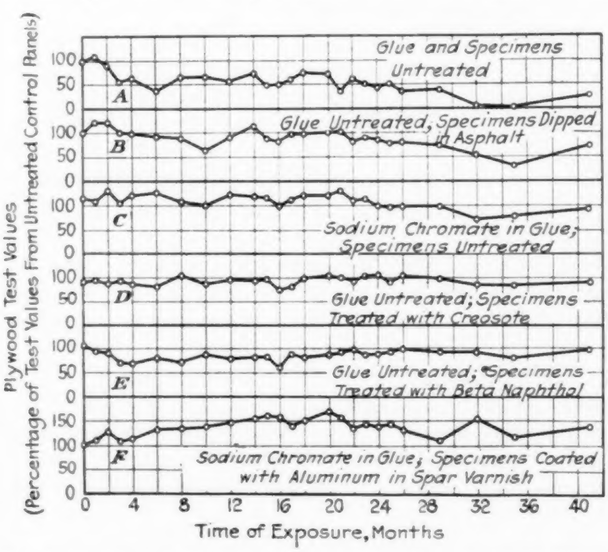


Fig. 2 Effect of Preservatives on the Durability of Glued Joints Made With Paraformaldehyde Blood Glue and Exposed to Relative Humidities Between 95 and 100 Per Cent

The two casein glues, Forest Products Laboratory formula 4B and the commercial casein glue, behaved so nearly alike that they may be considered together. Their test values have therefore been averaged to give results that may be considered typical for the more water-resistant casein glues.

Results of Tests

The results obtained up to the forty-first month are shown graphically in Figs. 1 and 2. In order to facilitate the comparison of one curve with another, each test value is plotted as a percentage of the control value, that is, a percentage of the average test value dry of the untreated, unexposed specimens. The curves representing the untreated controls therefore have initial test values of 100 per cent.

The effect of the treatment on the initial strength of the dry joint is difficult to estimate. The departure of the initial values of the various curves from 100 per cent may represent only normal variations in test values, or it may possibly represent the effect of the treatment on the strength of joint. There is no reason, however, to think that treating the glued plywood affected the initial strength of joint.

Untreated plywood glued with untreated casein glue (*A*, Fig. 1) failed completely after 24 months of exposure to conditions of high relative humidity and high mold concentration. Within the first three months the strength had dropped to half its original value. The failure seemed to be primarily in the glue line, although the wood had rotted by the time of complete failure.

With the specimens glued with casein glue and coated with asphalt the rate of failure was even more rapid than that of the untreated specimens (*B*, Fig. 1). The coating was evidently ineffective in increasing the durability of the joints.

Adding preservative (either beta naphthol or creosote) to the glue increased the durability so that final failure was delayed until at least the end of the thirty-second month (*C* and *D*, Fig. 1). Further, the test values remained above 50 per cent of the original for at least 22 months. The final failure in these cases seemed to be due to a rotting of the untreated wood. It seems safe to assume that the addition of preservative to the glue caused the glue at least to equal the wood in durability.

Adding preservative to the glue and then coating the untreated plywood with aluminum powder in spar varnish, (*E* and *F*, Fig. 1) did not markedly delay the final failure in comparison with specimens similarly glued but uncoated (*C* and *D*, Fig. 1). For at least the first 18 months, however, the test values of the aluminum-coated specimens were appreciably higher and the specimens were in better condition than the similar uncoated specimens. Coating plywood with aluminum powder in spar varnish generally increased the water resistance, as determined by the usual method of soaking for two days. This is to be expected to the extent that the coating retards the absorption of moisture during the soaking period.

Treating casein-glued specimens with beta naphthol was very effective in increasing durability (*G*, Fig. 1). At the end of the forty-first month these specimens still retain about 75 per cent of their original strength when dry. Treating with creosote seemed even more effective (*H*, Fig. 1). At the end of the forty-first month the average test values are almost as high as the initial test values.

Specimens glued with untreated blood glue are still hanging together at the end of the forty-first month. However, *A*, Fig. 2, indicates that they approached complete failure at 32 and 35 months. In other words, the resistance of the untreated paraformaldehyde blood glue resembles that of casein glue to which creosote or beta naphthol has been added (compare *A*, Fig. 2, with *C* and *D*, Fig. 1). This is not surprising since paraformaldehyde, which forms a part of the blood-albumin glue formula, undoubtedly has a beneficial effect on the durability of the joints.

Dipping plywood, glued with blood glue, in asphalt was noticeably effective in increasing durability (*A* and *B*, Fig. 2). The effectiveness of the asphalt dip was markedly greater on plywood glued with blood glue than on plywood glued with casein glue (*B*, Fig. 1). The experimental factors causing this discrepancy are unknown.

Several of the preservative treatments of blood glue and of plywood glued with blood glue have so increased the durability that, at the end of the forty-first month, the specimens are still intact and strong and it is difficult to judge their relative effectiveness (*C*, *D*, *E*, and *F*, Fig. 2). The sodium chromate treatments, however, are outstanding among the treatments involving the addition of preservatives to the glue.

Wood Decay. At the end of the twenty-sixth month, samples of the test specimens were examined for the presence of rot, and at least traces of wood-destroying fungi were found in all specimens. The conditions of exposure are apparently very favorable to the development of wood-destroying organisms, for wood treated with creosote seldom exhibits traces of fungus growth within a period of two years after treatment. Some of the less effectively treated specimens were so completely rotted that the wood lost the greater part of its strength. Obviously the testing of specimens of wood so decayed can give no indication of the strength of the glued joint, for the test is necessarily affected by the mechanical strength of the wood. These experiments were conducted on panels entirely of birch, which is not a decay-resistant wood. If a more durable species had been used, wood decay would have contributed less to the early failures and somewhat longer life might have been obtained when the glue alone was treated.

The tests have shown the possibility of greatly increasing the durability of plywood by treatments with beta naphthol in linseed oil or with creosote, both of which greatly retard the decomposition of the glue itself and protect the wood against the attack of wood-destroying organisms. Similar results can no doubt be obtained with other suitable toxics.

Contact Stresses in Gears

Comparison of Experimental Data With Those Obtained From Previously Derived Equations —Comparison of Magnitudes of Contact Stresses and Fillet Stresses—Information Regarding the Complete Stress Field in a Gear Tooth

By R. V. BAUD,[1] FRIEDRICHRODA, THURINGIA, GERMANY

WHILE it must be granted that much work, chiefly of a theoretical nature, has been carried out with regard to gear stresses, yet fundamental experiments have been relatively few. Since 1925 the author has done considerable work regarding fillet stresses by the photoelastic method, and from the viewpoint of pioneer work along these lines this phase of the work may be considered complete, at least from a practical viewpoint.

In so far as contact stresses are concerned, the basic equations were reviewed in a paper presented by Dr. S. Timoshenko and the author before the A.G.M.A. in 1926.[2] Two years later[3] the author derived the required stress equations for a line perpendicular to the gear-tooth profile at the point of maximum contact stress. Hereafter this line will be termed "contact center line." No experimental work had been done on this problem until 1930. In this work the main object was to find the fillet stresses for different positions of contact, one tooth carrying the total load.[4] After the fillet stresses were studied the author thought it advisable to use the same experimental set-up in carrying out some preliminary work on contact stresses, the results of which are given in this paper. The object of this additional work was threefold: (*a*) To compare the experimental data with the data as obtained by the use of the equations that were derived in 1928; (*b*) to compare the magnitude of contact stresses with fillet stresses; and (*c*) to obtain approximate information about the complete stress field in a gear tooth.

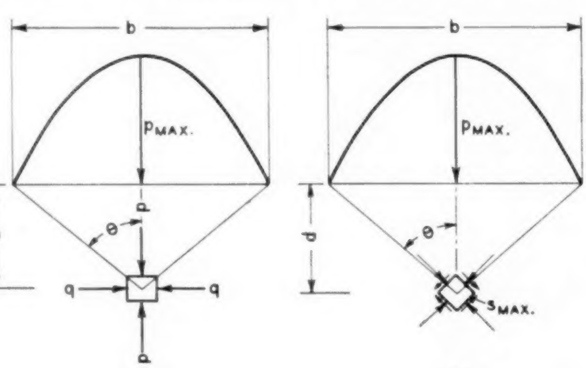


FIG. 1(*a*) SKETCH SHOWING WIDTH OF FLATTENING, PARABOLIC STRESS-DISTRIBUTION CURVE, AND ELEMENT WITH PRINCIPAL STRESSES p AND q

FIG. 1(*b*) SAME AS FIG. 1(*a*) EXCEPT THAT ELEMENT IS ORIENTED SO THAT SHEAR STRESS PARALLEL TO SURFACE PLANES IS MAXIMUM, S_{max}

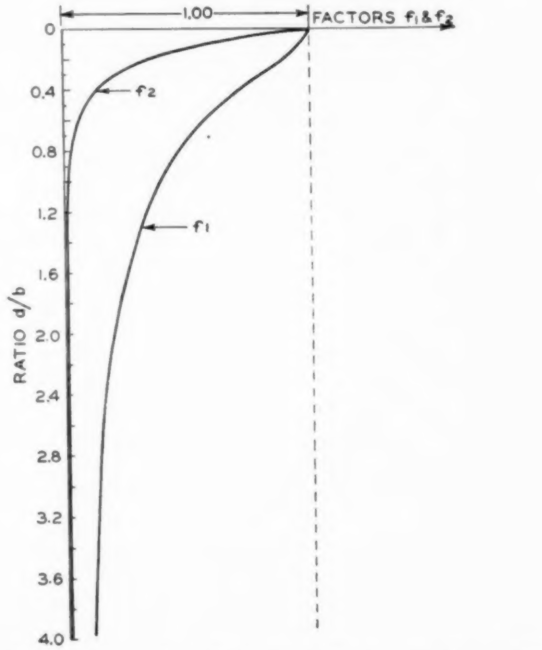


FIG. 2 FACTORS f_1 AND f_2 AS DEFINED BY EQUATIONS [1] AND [2]

I—THEORETICAL WORK

Referring to Fig. 1(*a*), the theoretical equations mentioned above are:

(*a*) *Principal Stress* (p) *Acting Along the Contact Center Line.*

[1] Until recently in charge of photoelastic stress analysis in the Mechanics Division of the Research Laboratories of the Westinghouse Electric & Manufacturing Co. Mr. Baud was graduated in 1920 from the Technical University of Zurich, having been a pupil of Professor Stodola. After one year of post-graduate work at the Technical University of Charlottenburg, he was employed by the German General Electric Co. in their offices at Berlin and Sao Paulo, Brazil, on power-plant work. Prior to taking up his work with the Westinghouse in the earlier part of 1925, he had charge of the layout of heating systems in New York. At present he is on a trip to Europe for the purpose of visiting various research laboratories and of conducting further studies in optics and mechanics. He is author and co-author of numerous scientific articles, the present one being the fourth devoted to gear research to appear in MECHANICAL ENGINEERING.

[2] Timoshenko and Baud, "Strength of Gear Teeth," MECHANICAL ENGINEERING, vol. 48, no. 11, p. 1108.

[3] Baud, "Study of Stresses by Means of Polarized Light and Transparencies," Proc. Eng. Soc. W. Pa., vol. 44, no. 6, pp. 230–232.

[4] Baud and Hall, "Stress Cycles in Gear Teeth," MECHANICAL ENGINEERING, vol. 53, no. 3, pp. 207–210.

$$p = f_1 p_{\max} = \frac{p_{\max}}{\pi}\left[2\left(\frac{1}{\tan^2\theta} - 1\right)\theta - \left(\frac{1}{\tan^2\theta} + 1\right)\sin 2\theta\right] \ldots\ldots\ldots [1]$$

The factor f_1 plotted for various ratios between the depth below the surface, d, and the width of the contact area, b, i.e., ratios d/b, gives curve f_1, Fig. 2.

(*b*) *Principal Stress* (q) *Acting Perpendicular to the Contact Center Line.*

$$q = f_2 p_{\max} = \frac{p_{\max}}{\pi}\left[\frac{4}{\tan\theta} + \left(1 + \frac{1}{\tan^2\theta}\right)\sin 2\theta - 2\left(1 + \frac{3}{\tan^2\theta}\right)\theta\right] \ldots\ldots\ldots [2]$$

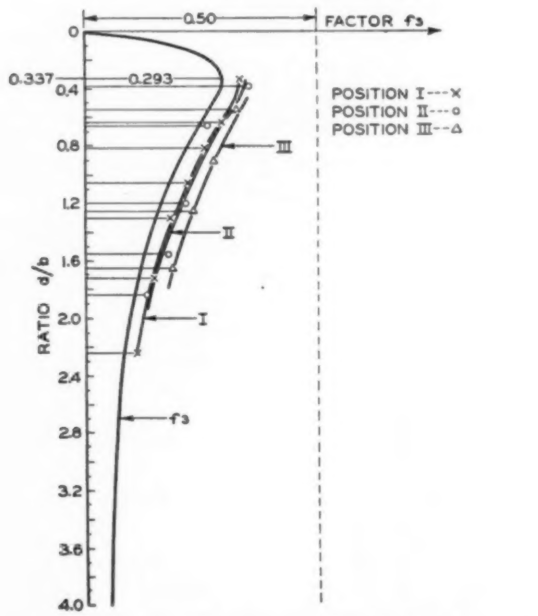


FIG. 3 EXPERIMENTAL AND THEORETICAL FACTORS f_3 AS DEFINED BY EQUATION [3]

The factor f_2 drawn in a similar manner to factor f_1 is shown by curve f_2, Fig. 2.

(*c*) *Principal Shear Stress* ($S_{\max}$) *Acting at an Angle of 45 Deg. to the Contact Center Line.* Referring to Fig. 1(*b*), the principal shear stress $S_{\max}$ is equal to half the difference between the principal stresses p and q. Therefore, by subtracting the terms of Equation [2] from those of Equation [1] and dividing the result by two, Equation [3] is obtained:

$$S_{\max} = f_3 p_{\max} = \frac{p_{\max}}{\pi}\left[\frac{2}{\tan\theta} + \left(\frac{1}{\tan^2\theta} + 1\right)\sin 2\theta - \frac{4\theta}{\tan^2\theta}\right] \ldots\ldots\ldots [3]$$

By definition the factor f_3 is half the difference between the factors f_1 and f_2 and is given by the curve f_3 in Fig. 3. The values of f_1, f_2, and f_3 are numerically given in Table 1. By balancing the plus and minus terms of Equations [1] and [2] it was found that the sum of the negative terms is always greater than the sum of the positive terms, indicating that for all ratios d/b the stresses are compressive stresses.

(*d*) *Maximum Contact Stress.* The value of $p_{\max}$, which is shown by a vector in Fig. 1, is obtained from the equation

$$p_{\max} = 1.5\,\frac{P}{b} \ldots\ldots\ldots\ldots\ldots\ldots [4]$$

TABLE 1 FACTORS f_1, f_2, f_3 FOR VARIABLE RATIOS d/b

Ratio d/b	θ	f_1	f_2	f_3
0	90°	1.0000	1.0000	0.0000
0.1	78.70	0.9670	0.5975	0.1848
0.2	68.20	0.8910	0.3560	0.2675
0.3	59.00	0.8000	0.2160	0.2920
0.337[1]	56.00	0.7650	0.1790	0.2930
0.4	51.35	0.7150	0.1350	0.2900
0.5	45.00	0.6370	0.0900	0.2735
0.6	39.80	0.5680	0.0573	0.2553
0.7	35.53	0.5120	0.0413	0.2358
0.8	32.30	0.4690	0.0286	0.2202
0.9	29.05	0.4260	0.0207	0.2026
1.0	26.56	0.3880	0.0159	0.1860
1.5	18.41	0.2736	0.0081	0.1328
2.0	14.03	0.1972	0.0052	0.0960
2.5	11.31	0.1619	0.0031	0.0794
3.0	9.46	0.1310	0.0026	0.0642
4.0	7.18	0.1020	0.0024	0.0498
5.0	5.71	0.0715	0.0021	0.0347
6.0	4.76	0.0410	0.0016	0.0197
10.0	2.87	0.0366	0.0012	0.0183
13.3	2.15	0.0296	......	......
28.6	1.00	0.0222	......	......

[1] For this ratio the factor f_3 is a maximum.

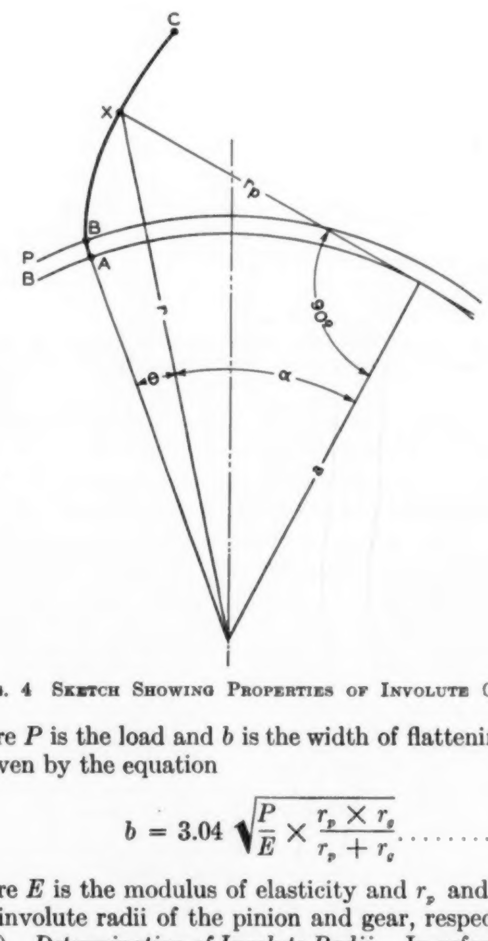


FIG. 4 SKETCH SHOWING PROPERTIES OF INVOLUTE CURVE

where P is the load and b is the width of flattening and is given by the equation

$$b = 3.04\sqrt{\frac{P}{E} \times \frac{r_p \times r_g}{r_p + r_g}} \ldots\ldots\ldots\ldots [5]$$

where E is the modulus of elasticity and r_p and r_g are the involute radii of the pinion and gear, respectively.

(*e*) *Determination of Involute Radii.* In referring to Equation [5] the involute radii are most conveniently

found without making a complete layout by the following methods, which are the same for both gear and pinion. Referring to Fig. 4, let r_p be the involute radius of the pinion, P the pitch circle, B the base circle of radius a, ABC the involute curve, and X any point on this curve having the polar coordinates θ and r. The polar equation of the involute curve is given by the equation

$$r = a \sec \alpha \ldots\ldots\ldots\ldots\ldots\ldots [6]$$

where α is the angle between r and a, and is of the magnitude as given by the equation

$$\text{inv } \alpha = \theta \ldots\ldots\ldots\ldots\ldots\ldots [7]$$

In this equation the term "involute α" represents the function (α— + tan α); it has been worked out in the form of tables,[5] in which θ is given in radians for various values of α in degrees and minutes.

One method of finding the involute radius r_p, i.e., the length of the generating line, is then given by the equation

$$r_p = a\ (\theta + \alpha) = a \tan \alpha \ldots\ldots\ldots [8]$$

For the active part of the involute the angle θ is very small, and if measured from the drawing, extreme accuracy is required. For this reason the second method is better. This consists of measuring r directly from the drawing and applying the equation

$$r_p = \sqrt{r^2 - a^2} \ldots\ldots\ldots\ldots\ldots [9]$$

since by definition of an involute curve the angle between a and r_p is always 90 deg. The second method has the advantage that r can be measured more accurately than can small values of θ.

(*f*) *Numerical Example for Contact-Stress Calculation.* Assuming a load P of 242 lb. per inch of face, and a modulus of elasticity E for celluloid of 359,000 lb. per sq. in., the values as given in Table 2 were obtained for a set of gears having the pitch diameters 52.000 in. and 17.714 in., a pressure angle of 20 deg. and a diametral pitch of $1^3/_4$.

TABLE 2 RADII, AMOUNT OF FLATTENING, AND MAXIMUM CONTACT STRESS FOR THREE POSITIONS TESTED, FIGS. 5 TO 7

	Position		
	I	II	III
r_{pinion} in inches	2.236	3.490	5.145
r_{gear} in inches	9.630	8.607	6.417
b, inches	0.10617	0.12436	0.13336
p_{max}, lb. per sq. in.	3420	2920	2720

By combining the information given in Tables 1 and 2, the stresses can be computed for any point along the contact center line. It must be clearly understood, however, that farther away from the point of maximum contact stress Equations [1]–[3] are approximate because of the finite dimensions of the gear tooth. For points between the contact center line and the fillets there are additional stresses produced by the shear and bending action of the load, and consequently new equations must be derived for these points to contain all the stresses at work.

[5] Buckingham, "Spur Gears," pp. 56–68.

II—Experimental Work

In order to compare the foregoing theoretical results with experimental data, photoelastic tests were made. It is well known that on the basis of such tests the S_{max} stress field can be obtained in a comparatively simple manner; whereas analytically the problem has been solved for the contact center line only, as discussed above, since many difficulties are encountered in solving for other lines.

The gear and pinion of the dimensions mentioned were tested in three different angular positions by using the loading arrangement shown in Fig. 8, and the photographs, Figs. 5 to 7, were obtained. In order that these pictures may be more clearly understood, lines of equal shades have been traced—see Figs. 9 to 11. The figure given on each line of these tracings represents the ratio f_3 as defined by Equation [3] as the ratio between the principal shear stress S_{max} and p_{max}. Therefore, in order to obtain S_{max} at any point of the tooth it is only necessary to multiply f_3 for this point by the maximum compression stress p_{max} as computed from Equations [4] and [5], and as given for each of the three positions of the gear and pinion in Table 2.

The lines for S_{max} intersect the contact center line at certain points, for which the theoretical ratio f_3 is given by the theoretical curve f_3 in Fig. 3. This permits a comparison between the experimental and analytical values of f_3 for the contact center line. In plotting the experimental values of f_3 for the three positions I to III, the curves I to III in Fig. 3 were obtained. It will be seen that they agree closely with the theoretical values represented by the curve f_3, particularly if it is realized that certain experimental determinations were not made with the greatest accuracy, since, as was mentioned in the introduction, the contact study was given only secondary importance at the time the experiments were performed. The main object of the investigation was to obtain the fillet stresses, which are given in Table 3 together with the contact stresses for the purpose of comparison.

TABLE 3 COMPARATIVE DATA BETWEEN GOVERNING STRESSES AT THREE POINTS OF THE CELLULOID PINION

Position	Contact	Fillet	
	p_{max}	p_c	p_T
I	3420	830	880
II	2920	1160	970
III	2720	2160	1400

From this table it is seen that in the driving pinion the contact stress decreases and the fillet stresses increase as the pinion rotates. This tendency to converge is therefore a maximum at the point of disengagement.

III—Application of Investigation to Steel Pinion

The question arises whether the stresses photoelastically obtained with transparent materials are directly applicable to gears made of different materials, for instance, of steel. This can be answered in the affirmative, provided the width of contact in the transparent gear, b_t, is equal to the corresponding

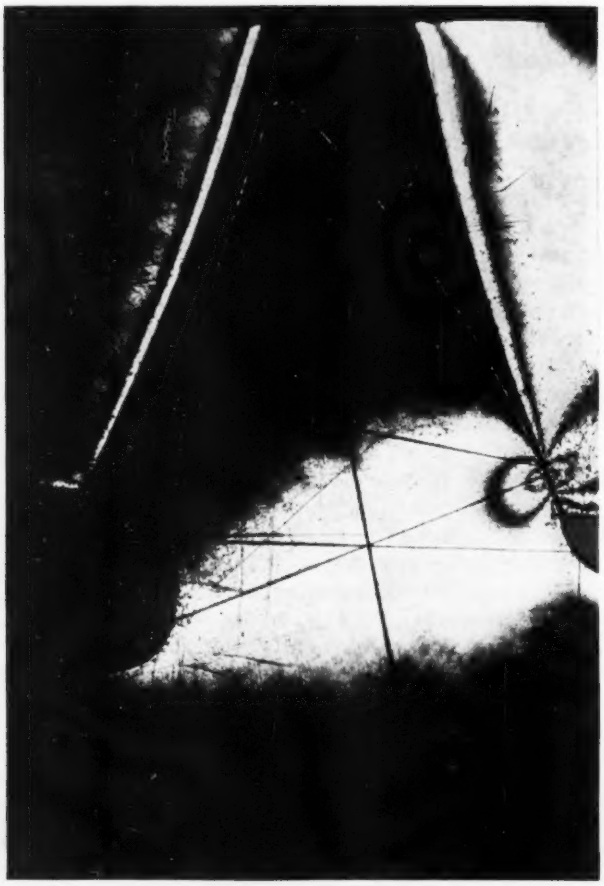


FIG. 5 PHOTOELASTIC PICTURE OF GEAR TEETH AT POSITION I

width, b_s, in the steel gear. The above requirement, that

$$b_t = b_s \ldots\ldots\ldots\ldots\ldots\ldots [10]$$

results in the relationship

$$\frac{P_t}{P_s} = \frac{E_t}{E_s} \ldots\ldots\ldots\ldots\ldots\ldots [11]$$

where p_t and P_s denote the loads applied, and E_t and E_s are the moduli of elasticity of the transparent material and steel.

In the experiment the load was 242 lb.; this corresponds to a load on the steel pinion equal to

$$P_s = P_t \frac{E_s}{E_t} = 242 \frac{30{,}000{,}000}{359{,}000} = 20{,}200 \text{ lb. per inch of face}$$

The reason for using this excessive load was to obtain in the fillets of the celluloid model, stresses of such magnitude as to be readily measured with good accuracy.

For the above load of 20,200 lb. all results are strictly correct. Consequently, to obtain the principal shear stress S_{max} at any point, take the value of the factor f_3 of this point from Figs. 9 to 11 and multiply it by p_{max} as obtained from Equations [4] and [5] for 20,200 lb. Further on, another method is adopted, which consists in computing first the stresses for the celluloid pinion as discussed and in multiplying these stresses by the load ratio r, i.e., the ratio between the load considered, 20,200 lb., and the model load, 242 lb.

From this it is seen that the experimental results strictly hold for but one particular load. For other loads the results are approximate. The questions therefore arise, when only one experimental load is used, if and how the stresses can be computed from the test values for loads that differ from the one obtained by applying Equation [11], for instance, 4150 lb. This is the extreme static load for this particular pinion. For other loads the same reasoning should be applied.

The stresses that are due to the bending and shear action of the load must be multiplied by the load ratio as defined before; $r_1 = \frac{4150}{242} = 17.2$ in this case. Assuming that the fillet stresses are due to these causes alone, the values given in Table 4 were obtained by multiplying the corresponding ones of Table 3 by 17.2.

The stresses that are due to the direct action of the applied load, such, for instance, as the maximum contact stresses given in column 1 of Table 3, must be multiplied by the factor $k = r_2 c = 37.85$ as defined and derived in the Appendix. This results in the values given in column 1 of Table 4.

The values of the maximum contact stresses can, of

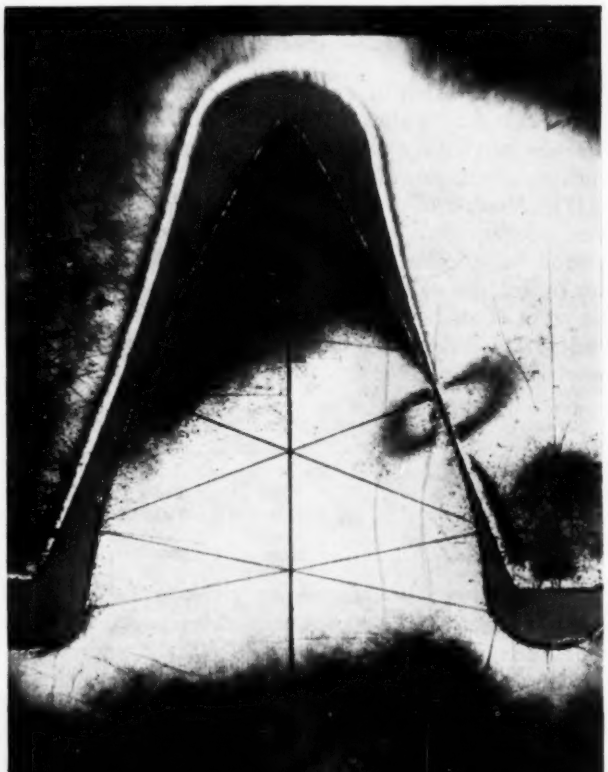


FIG. 6 PHOTOELASTIC PICTURE OF GEAR TEETH AT POSITION II

course, also be computed directly, without resorting to the factor k, from Equations [4] and [5]:

$$b = 3.04 \times \sqrt{\frac{4150}{30{,}000{,}000} \times \frac{2.23 \times 9.63}{2.23 + 9.63}} = 0.0482$$

$$p_{\max} = 1.5\,\frac{4150}{0.0482} = 129{,}200$$

which agrees for position I with the value given in Table 4 within the accuracy of slide-rule calculations.

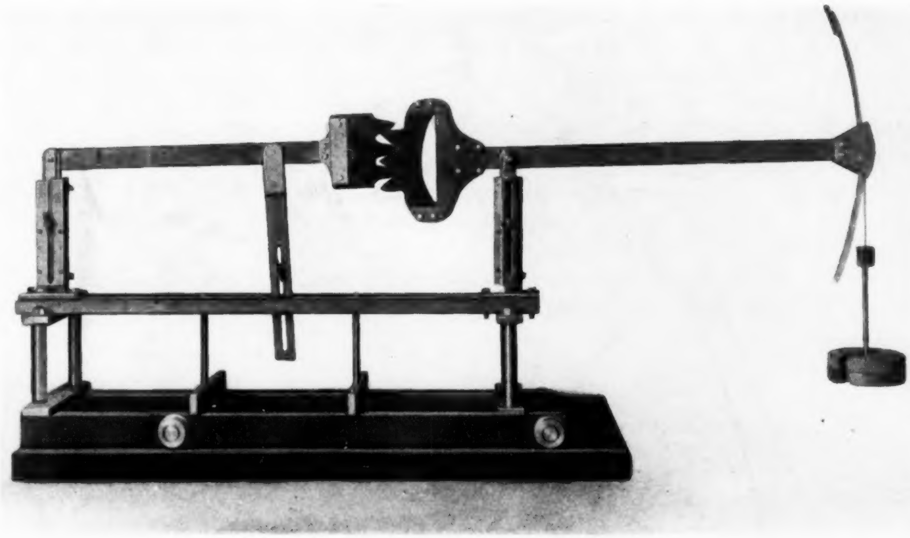


Fig. 8 Loading Device Used in Experiments

From this table it is seen that at the position III, which is close to disengagement, the maximum contact stress is still 2.77 times as large as the compression stress in the fillet.

The fillet stresses given in Table 4 would be entirely correct if they were due only to bending and shear action of the load as assumed. Recent considerations have led us to believe that the observed fillet stresses are also composed of two parts, namely, one that is due to bending and shear action, and the other due to compression radiating from the contact area. The latter stress for the compression side of the tooth can be computed for position I approximately from Equation [1], even though the point of maximum fillet stress is not exactly on the contact center line for this position. The ratio d/b is 13.3, and, according to Table 1, the factor f_1 for this ratio is equal to 0.0296, which corresponds to a stress of approximately 3 per cent of $p_{\max}$, or 100 lb. per sq. in. For this reason the stress of 830 lb. per sq. in., given in Table 3, must be divided into two parts, of which the greater part, namely, about 730 lb. per sq. in., is the stress produced by bending and shear and must be multiplied by the factor r_1 = 17.2, while 100 lb. per sq. in. is due to the radiating compression and must be multiplied by the factor k = 37.85. This results finally in a total fillet stress for the pinion equal to 16,335 lb. per sq. in., instead of 14,270 lb. per sq. in. as given in Table 4. All fillet stresses listed should be computed in a similar manner, but because of large deviations of the straight lines through the points in question from the contact center line, it is doubtful whether Equation [1] is applicable.

TABLE 4 COMPARATIVE DATA BETWEEN GOVERNING STRESSES AT THREE POINTS OF THE ACTUAL STEEL PINION

Position	Contact $p_{\max}$	Fillet p_c	Fillet p_T
I	129,300	14,270	15,130
II	110,500	20,100	16,680
III	102,800	37,150	24,080

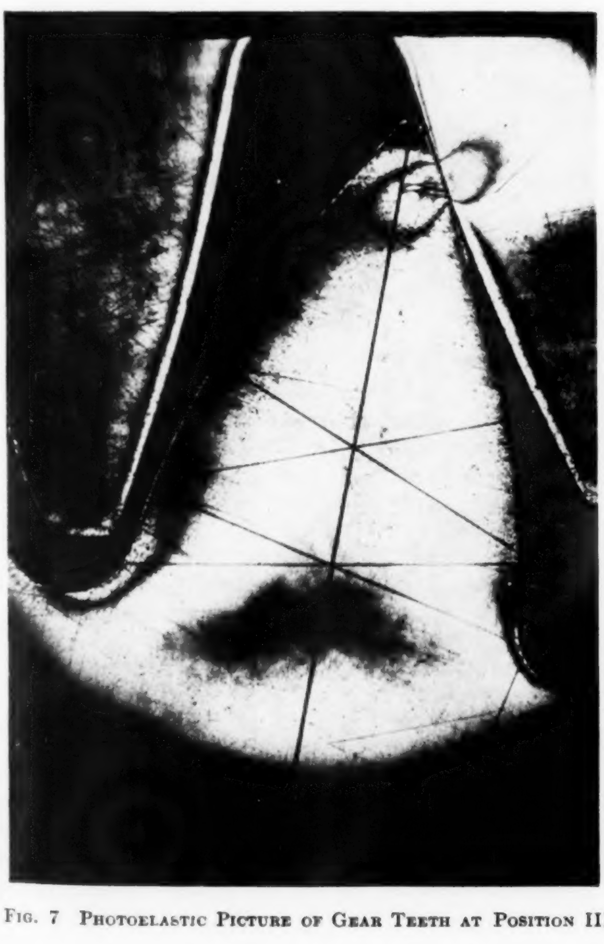


Fig. 7 Photoelastic Picture of Gear Teeth at Position III

The foregoing discussion holds for all points below the contact center lines. For these points the principal shear stress $S_{\max}$ for the celluloid pinion is equal to $f_3 \times p_{\max}$. Again, one portion of $S_{\max}$ is due to the bending and shear action of the external load, and the remainder is due to contact. In order to obtain the stresses in the steel pinion, the first part must be multiplied by r_1 and the other by k. Unfortunately, for most

parts of the tooth it is not known just how S_{max} divides. This division is not algebraic. It should be clearly understood that for loads which satisfy Equation [11], only one load ratio and no factor are required, and the application of the photoelastic results is extremely simple.

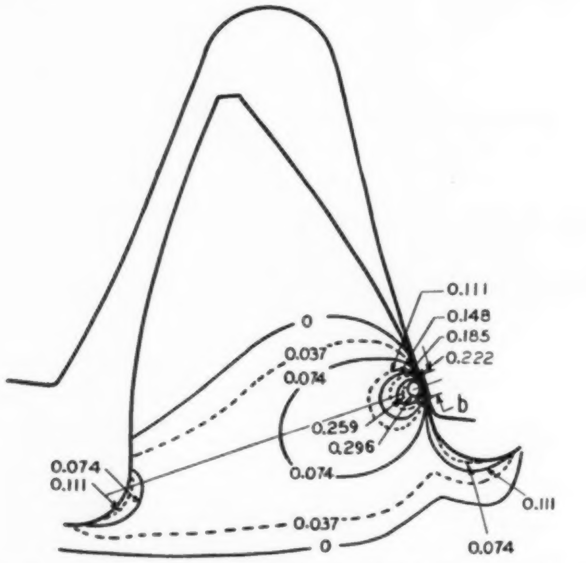


FIG. 9 LINES SHOWING CONSTANT VALUES OF S_{max} AS TRACED FROM FIG. 5

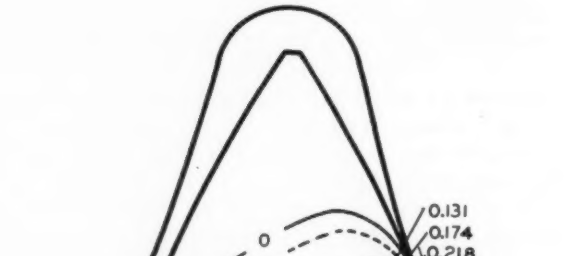


FIG. 10 LINES SHOWING CONSTANT VALUES OF f_3 OR S_{max}, RESPECTIVELY, AS TRACED FROM FIG. 6

IV—CRITICAL STRESSES IN STEEL PINION

In the heat-treated portions of the gear, where ductility has been sacrificed, the principal stress p or q must be considered; in the ductile portions, the ultimate shear stress. By "ultimate shear stress" is meant the largest of the three principal shear stresses that are acting. An indefinitely large number of planes can be passed through a point, and in each one the shear stress has a certain definite value. However, for practical considerations the number of planes can be reduced to three, such that the shear stresses in these three planes are a maximum and are called "principal shear stresses." Their magnitudes are equal to one-half the difference between the three principal stresses p, q, and r and are expressed by the equations

$$\left.\begin{aligned} S_z &= S_{max} = \frac{p-q}{2} \\ S_y &= \frac{p-r}{2} \\ S_x &= \frac{q-r}{2} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots [12]$$

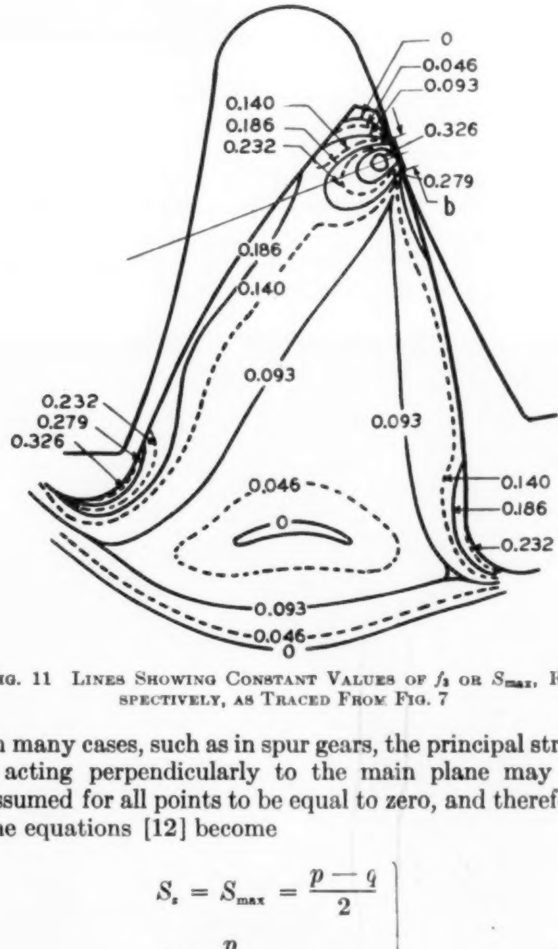


FIG. 11 LINES SHOWING CONSTANT VALUES OF f_3 OR S_{max}, RESPECTIVELY, AS TRACED FROM FIG. 7

In many cases, such as in spur gears, the principal stress r acting perpendicularly to the main plane may be assumed for all points to be equal to zero, and therefore the equations [12] become

$$\left.\begin{aligned} S_z &= S_{max} = \frac{p-q}{2} \\ S_y &= \frac{p}{2} \\ S_x &= \frac{q}{2} \end{aligned}\right\} \quad \ldots\ldots\ldots [13]$$

In case p and q have different signs, the principal shear stress S_{max} is the ultimate shear stress and acts in the main plane as shown in Fig. 12. If, however, the signs of p and q are the same, i.e., both tension or both compression, then the ultimate shear stress will be equal to $p/2$, Fig. 13, or $q/2$, Fig. 14, depending upon

whether p is larger or smaller than q. From this it is seen that the ultimate shear stress may act either parallel to the two main surface planes of the gear tooth, Fig. 12, or may act along the intersection of two planes, namely, the plane through the direction of the smaller principal stress and inclined 45 deg. to the surface planes, and the plane through the direction of the larger principal stress perpendicular to the surface planes, Figs. 13 and 14.

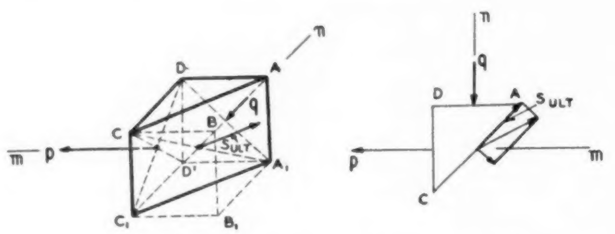


FIG. 12 CONDITION SHOWING $S_{ult} = (p - q)/2$

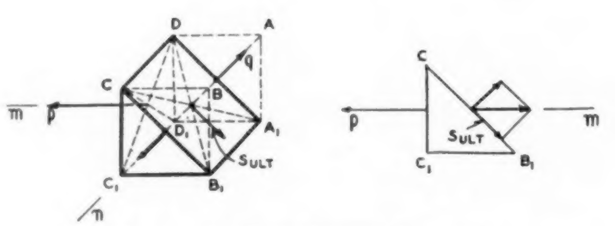


FIG. 13 CONDITION SHOWING $S_{ult} = p/2$

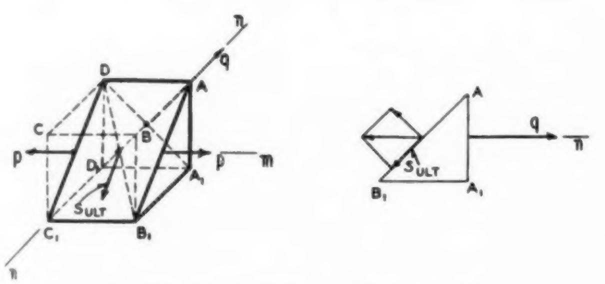


FIG. 14 CONDITION SHOWING $S_{ult} = q/2$

Using the above reasoning in the case of the contact center line in the gear tooth, it becomes evident that the ultimate shear stress is equal to $p/2$ and acts as shown in Fig. 15. From this it follows that the determination of p is very important and is the governing factor, regardless of whether the material is ductile or not. It determines principally the wear, although the q-stress also may contribute to this detrimental effect.

From the viewpoint of breaking strength, the tensile stress p_T and the compression stress p_C in the fillets must be considered.

CONCLUSIONS

From this investigation the following conclusions may be drawn:

a The experimental curves and the theoretical curve for f_3 have the same characteristics, but the experimental curves have somewhat higher values. It is believed that if the experiments had been made with utmost care these curves would closely coincide for points on the contact center line near the contact area, and so furnish a conclusive experimental proof for Equation [3].

b As the driving pinion rotates, the contact stresses decrease and the fillet stresses increase. This tendency to converge is therefore a maximum at the point of disengagement. At position III, which is close to disengagement, the stress ratio between the maximum contact stress and the compression stress in the fillet is, for the pinion studied and a load of 4150 lb., still larger than $2^1/_2$. Incidentally, this ratio decreases for increasing loads.

c Both principal stresses along the contact center line are compression stresses, consequently the ultimate shear stress is half the larger principal stress, the stress p in this case. It is the one that has to be considered for the material along the contact center line which is not affected by heat treatment. Where ductility is sacrificed, the principal stress p must be considered. From this it follows that p is the governing stress regardless of the properties of the material; it determines principally the wear.

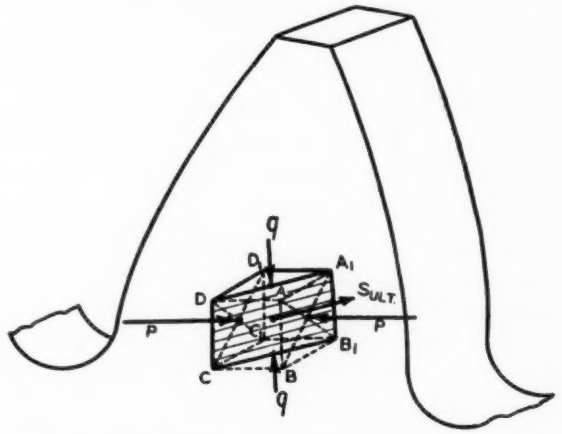


FIG. 15 GEAR TOOTH SHOWING DIRECTION OF $S_{ult} = p/2$

d If the experimental load is chosen in accordance with Equation [11], the stresses in the actual machine part are obtained by multiplying the stresses in the transparent model by the load ratio. If, on the other hand, Equation [11] is not satisfied, the model stresses must be divided into two parts, which in order to obtain the stresses in the actual machine part, must be multiplied by the factors r_1 and k, respectively. Both parts must then be added, but this addition is not simply algebraic.

e Since for celluloid the choice of the load is not entirely at will, and since considerable difficulties are experienced in transforming the results from model to actual machine part for loads that are not representative, a transparent material should be available, which allows a greater freedom in the choice of the load. Bakelite is such a material, for reasons that are discussed in the Appendix.

Acknowledgment

The author wishes to express his appreciation to Mr. E. Hall for making the photographs, Figs. 5 to 7, and to Mr. G. G. Fornes for help in the computation.

Appendix

IN THIS Appendix is given the determination of the factor k, and a discussion of why bakelite is preferable to celluloid for stress-field studies in gears.

(*a*) *Determination of* (k). The load on the model that corresponds to the load 4150 lb. on the actual pinion is determined from Equation [11] as follows:

$$P_t = P_s \frac{E_t}{E_s} = 4150 \frac{359{,}000}{30{,}000{,}000} = 49.4 \text{ lb.}$$

For the 242-lb. load that was actually used in the experiment the maximum contact stress is given by Equation [4],

$$p_{\max(242)} = C_1 \frac{242}{b_{242}}$$

where C_1 is a constant and b_{242} is the width of flattening for a load of 242 lb. and is given by Equation [5]:

$$b = C_2 \sqrt{242}$$

From this it follows that

$$p_{\max(242)} = C \frac{242}{\sqrt{242}} = C \sqrt{242}$$

Similarly, for a load of 49.4 lb.,

$$p_{\max(49.4)} = C \sqrt{49.4}$$

It follows by division that

$$\frac{p_{\max(49.4)}}{p_{\max(242)}} = \sqrt{\frac{49.4}{242}} = 0.452 = c$$

i.e., the maximum contact stress for a load of 49.4 lb. is 0.452 times the maximum contact stress at 242 lb. Furthermore the load ratio r_2 in this case is equal to 4150/49.4 = 84. Therefore the final factor k is as follows:

$$k = r_2 c = 84 \times 0.452 = 37.85$$

(*b*) *Advantages of Bakelite.* The author suggests that further experiments of this nature should be made using bakelite, provided models free from initial stress are obtainable. The ratio between the moduli of bakelite and steel is about 1/40, so that the model load becomes in this case

$$P_t = P_s \frac{E_t}{E_s} = 4150 \times 1/40 = 103.5 \text{ lb.}$$

With a load of 103.5 lb. the fillet stresses are reduced in the ratio 103.5/242 = 0.43. But, due to the fact that bakelite is about five times more sensitive than celluloid, the shift in the phase between the two refracted rays is 5 × 0.43 = 2.15 times greater in bakelite with a load of 103.5 lb. than in celluloid with a load of 242 lb. Consequently there is ample stress produced in the fillets and yet Equation [11] is satisfied. In fact, the load on a model made of bakelite can be reduced from the one computed, 103.5 lb., without sacrificing the accuracy of the readings in the fillets, so as to correspond to the customary contact load.

Research in Industry

MODERN technical scientific research demands of its practitioner a thorough knowledge of the fundamental physical and chemical sciences. Unfortunately it is seldom that both of these groups of knowledge are represented to a sufficient degree in one and the same person, which is becoming more and more desirable. I have in mind a problem such as combustion, one of the most commonplace phenomena in fact. It has been attacked by steam experts, and it has been worked at by chemists, but as yet we know very little about the matter.

Technical scientific research work should begin with a study of the literature, a collection of the knowledge which already exists in different quarters pertaining to the problem in question. A mathematical analysis should be undertaken in so far as it is possible. Then will follow the experimental investigation, if possible reverting to the intrinsic elementary process in conjunction with the fundamental laws of physics and chemistry. For this, scientific methods of investigation and instruments will be used, and it is therefore necessary that a thorough knowledge of these shall not be wanting. The best prospect of success will be presented if the research practitioner has at the same time an open mind for, and preferably practical experience of, technical matters, so that he will see the technical perspective of the scientific experiment. On the whole, it is, of course, necessary that he shall have good sound judgment, which is required, indeed, in every connection in this life.

A person who perchance is not in possession of all the knowledge of a natural scientific character referred to above may, nevertheless, with just claims to scientific working, solve technical problems of a less complicated nature—and many such crop up—if he will but apply logical thought to them. On the other hand, it must be admitted that there is a whole lot of quasi-scientific matter. There are people who collect knowledge in the same way that one collects stamps, who habitually make use of the coded terms of the various branches of science, but who lack the capacity for the coordination of thought. Such augurers are unfortunately not rare, and they do harm by awakening distrust of the word "science" in the mind of the practical man of industry, and cause him to overlook the invaluable services which well-qualified technical scientific research is capable of rendering.—Dr. Axel Enström in an address reported in *The Engineer*, June 5, p. 632.

Product Design for Increased Utility and Improved Marketability

By GEORGE S. BRADY,[1] NEW YORK, N. Y.

PRODUCT design, or product engineering, is a new function which has come into being only just recently. There has always existed the function of design relating to the product, but product design as a complete function in itself that not only sees the technical design of the product but also visualizes it in its entire scope from inception to its place in the hands of the customer, is so new that many designers have not yet grasped its significance.

A recently created department of one of the largest mail-order houses—a house that markets thousands of different classes of articles—controls the entire production of a number of different factories. This department is for the selection of new items for sale and for suggesting the improvement of existing items. In choosing leaders for this department the management has not selected engineers nor designers. The chief is a retired army officer, and his principal assistant is what in modern parlance might be called a psychologist. Now engineering has always been looked upon as an exact science, and anything directly relating to mechanical design most certainly is. But that is where a danger lies when it comes to visualization of the whole product for the creation of something that can be sold. The engineer who works close to mechanical details is likely to forget that the buying public has no interest at all in his ingenious link motions, in his accurate gear teeth, nor in the type of finish he uses. The public sees only the ultimate end accomplished by the motion. It is only interested in the lack of noise of the gears, and it wants appearance and durability in the finish without worrying whether it is enamel, paint, or lacquer. Lately the engineer has even had to box up the mechanism of his product where it cannot be seen nor heard, and also to provide as nearly as possible permanent lubrication so that no attention is required during the life of the product. The electric refrigerator is a good example of such a product.

Sales Value the Ultimate End to Be Sought in a Product

Sales value is the ultimate end to be sought in any product. From the standpoint of the plant owner the product is valueless if it cannot be sold. Until very recently it has been the sales department that has had to assume entire responsibility for sales. But lately there has been a decided swing in the other direction, and the engineering department is being made to take responsibility when a product does not sell as readily as it should. It was not long ago when the average plant hired salesmen to sell products that had been designed and put in production with little or no study of any economic or psychological problems involved. If the product did not sell it was the fault of the salesmen.

Reviewing hastily the history of our so-called machine age, we note that at the very outset, about a century and a quarter ago, textile machines and mill machinery were invariably built in the shop in which they were to be operated. The only question asked was whether the machine would work. Later, just a hundred years ago, when plants sprang up independently in large numbers to specialize in building the engines and locomotives then being called for, there were plenty of indications of rivalry and competition. The foundries were boasting about who was making the largest castings, which were going into marine-engine beds at that time. There was also much ornamentation of machinery, but later on, when mass production entered into machine building, this ornamentation was entirely lost.

Machine designers, and engineers responsible for the engineering development of many kinds of metal products, should have awakened to their responsibilities in putting sales appeal into their product long before they did. In fact, they were apparently not even quick to discern what had happened in the automobile industry. Even looking into that industry, which we usually take as the leader, we find that the engineer at first resisted, rather than initiated, the first advances of design for appearance and customer appeal.

Automotive Industry Leader in Meeting Customers' Requirements

But to the automotive industry does belong the credit for being the leader in giving the customer what he desired. Years ago systems were devised to take the complaints and suggestions coming from the service stations and turn them over to the engineers. Efforts were made to overcome all serious objections, and each new model incorporated more and more of the users' ideas. A few other manufacturers, such as at least one large typewriter company, had systems for making use of field suggestions and of cooperating with the sales department. But the average run of plants until a very recent date permitted their engineers to burrow deep in the intricacies of pure theoretical engineering and to forget the ultimate object of pleasing the customer.

Beginning with the depression of 1921, *American Machinist* ran a "modernization campaign" to awaken designers of machine tools to the possibilities of building new business by throwing aside old standards and put-

[1] Managing Editor, *Product Engineering*.

Presented at an informal management conference held under the auspices of the Management Division of the A.S.M.E., New York, April 3, 1931. Slightly abridged.

ting into their products every possible item that would increase productive capacity and fit the conditions to be found where the tool was installed. This meant not only looking to the general design, but also to the materials of construction and to the building in of special units such as motors and automatic oiling systems that would decrease maintenance and make better conditions in the customers' plants.

No one can estimate the far-reaching effects of this campaign, which was given much publicity and joined in heartily by other journals and by the engineering societies. The new industry of radio recognized at the very outset the importance of sales appeal and fitted its products to the customers' needs. But unfortunately the doctrine has not been fully grasped by all engineers. Within the past year there have been several articles in such magazines as *Printers' Ink* and *Advertising and Selling*, advocating and suggesting to management that engineering departments be placed under the jurisdiction of sales departments. To us engineers such an arrangement may seem ridiculous, but we had better wake up to the fact that there is reason behind it. If a chief engineer or a designer responsible for product development is not ready and willing to take responsibility for the sales value of his product, then he needs some one over him who will. Isn't the secondary position of the engineer in many organizations due to his own inability or lack of desire to assume a position of responsibility for the ultimate success of the product for which the plant exists?

Cooperation of Engineering and Sales Departments

There are many ways of organizing the product engineering of a manufacturing plant. One method that is working with great success in a number of plants is to place the engineering department under an executive officer who ranks equally with the officer in charge of sales and with the manager of the production activities. Where the function is thus definitely recognized as being on an equality with other branches there is a means created for direct coordination of effort and an immediate realization that, after all, the finished product is the sole reason for the existence of the factory.

At the Easy washer plant in Syracuse, which is typical of the best practice today, the chief engineer has an office apart from the engineering department, which latter is supervised by a chief draftsman. He is in constant contact with the sales manager, and his main task is visualizing and dreaming about finished washing machines that will meet customers' needs rather than about details of ways in which technical problems are to be solved.

At the Yellow Coach plant of the General Motors Corporation the chief engineer has an office in the executive building alongside the executives of other functions, and he has another office in the separate engineering building. The procedure of cooperation with sales is about the same as that mentioned above, but, being a larger organization, more money goes into direct new-product research, and there is one section of the engineering department made up of engineers who spend all of their time in pure research for new things that might never develop either in the field or in the course of regular engineering design. Most large companies have such pure-research departments today.

The task of the chief engineer today is something different from what it was a generation ago when there were few construction materials and when practically all parts and units were made in his own shop. Today the word "steel" has no specific meaning to the product engineer, as he may be using ten or even fifty varieties of steel in his one product—each the most economical for its particular purpose. Likewise today the product engineer will not listen to the management to "keep the machines in the shop busy" in making parts and units if he can buy them more economically from parts specialists.

Importance of Making Products That Are Pleasing to the Eye

What can the product engineer do to increase salability through appearance in the product? The answer here also is that he, in cooperation with the chief of sales, must gather together the complaints, suggestions, and commendations of the users, weigh them carefully, and incorporate those that in his judgment are practical and which his cooperation with the shop executive shows him can be made economically. Usually the final result is a compromise with the original suggestion. Occasionally it goes even further in advance than the idea of the original suggestion.

Many plants nowadays call in an outside artist, or even a sculptor, to view the work of the engineers before the job is put into production. One of the largest electric-machinery builders has a full-time "art director" who goes over every piece of machinery after it is designed to suggest lines that might be more pleasing to the eye. A typewriter plant has one man continually experimenting with the appearance factor, and the result has been that this company was the pioneer in bright-colored typewriters, and also opened an entirely new field of home typewriters for ladies' boudoirs by two- and three-colored lacquer jobs and bright chromium plate that might have appeared laughable to the serious-minded designers of a few years ago. He also learned the likes and dislikes of the foreign markets of the company, and by the incorporation of certain appearance factors was able to build sales and take the leading position in those fields, even against the competition of low-priced German machines.

A book could easily be written on what the product engineer should look for in salability and utility factors in the various fields of materials, finishes, art and form, noise elimination, automaticity, and what might well be termed "foolproofness," or the ability of the product to "stay on the job" continuously without the necessity for tinkering, oiling, or service of any kind. In fact, on some of these subjects there is a notable lack of published information.

Survey of Engineering Progress

A Review of Attainment in Mechanical Engineering and Related Fields

Data on the Operation of Loeffler Boilers

THIS is an extensive article which cannot be completely reported because of lack of space. Only certain parts will be touched upon here.

According to the author, the Loeffler boiler is of practical advantage for use in plants where the steam condensed after taking part in cooking or heating cannot be returned to the boiler because of its contamination in the process. Where ordinary boilers are used in such cases, considerable amounts of make-up water have to be employed, this water being chiefly prepared by distillation, which is not economical. Where the Loeffler boiler is used, simple chemical water purification is sufficient.

Steam circulation requires, of course, the expenditure of a certain amount of energy, which becomes, however, smaller as the volume of steam to be circulated decreases, or as the pressure of the steam and temperature of the feedwater increase. At pressures from 120 to 130 atmos. the consumption of energy due to circulation is very low. As a matter of fact, under certain conditions, because of the small amount of energy consumed in circulation, it pays to operate the Loeffler boiler at 120 to 130 atmos. and use a 60-atmos. pressure in the machine driven by the steam.

The following is intended to express the numerical connection between the weight of the steam given out by the Loeffler boiler and that circulated in it. The evaporating drum receives D kg. of live steam of heat content i kg-cal. per kg. While D_1 kg. of saturated steam with a heat content i_s kg-cal. per kg. is taken away, the difference $(D_1 - D)$ kg. representing the net weight of the steam given out. This difference must be generated on one hand by means of the superheat of the steam produced from the water in the evaporating drum, the energy of which may be set as u'_s kg-cal. per kg., in addition to which a weight of feedwater equal to $(D_1 - D)$ kg. must have its energy raised from u' to u_s'. The whole process is expressed in the equation:

$$D\,(i - i_s) = (D_1 - D)\,(i_s - u'_s) + (D_1 - D)\,(u'_s - u')$$

From this the following expression is obtained for the ratio between the weights of the steam given out and steam circulating;

$$\frac{D_1 - D}{D_1} = \frac{i - i_s}{i - u'}$$

For example, if the boiler operates with pressure of 130 atmos. and a temperature of 480 deg. cent. (896 deg. fahr.) and if the feedwater has a temperature of 260 deg. cent. (500 deg. fahr.),

then $i = 787$
$i_s = 624$
$u'_s = 356$
$u' = 270$ kg-cal. per kg.

and hence

$$\frac{D_1 - D}{D_1} = \frac{163}{431} = \frac{1}{2.65}$$

which means that the weight of the steam which has to be circulated is 3.2 times that of the steam given out. The weight of steam to be circulated would be at a minimum when and if the feedwater could be brought to the evaporation temperature, and with $u' = u'_s = 356$ kg-cal. per kg.,

$$\frac{D_1 - D}{D} = \frac{1}{2.65}$$

The profound influence of the preheating of feedwater on the amount of energy consumed in circulation is numerically shown in Fig. 1, which also indicates the relation between the volume of

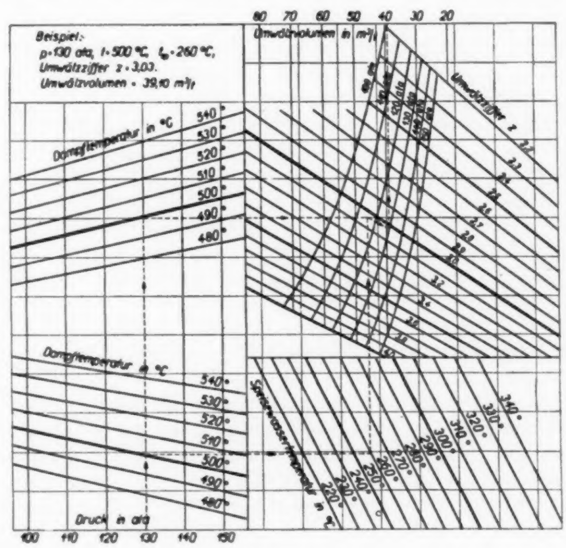


FIG. 1 DATA ON CIRCULATION

(*Beispiel* = example; p = 130 atmos. abs.; t = 500 deg. cent.; tsp = 260 deg. cent.; *Umwälzziffer* z = circulation coefficient z = 3.03; *Umwälzvolumen* = circulation volume = 39.10 cu. m. per ton; *Umwälzvolumen in* m^3/t = circulation volume in cu. m. per ton; *ata* = atmosphere absolute; *Umwälzziffer* z = circulation coefficient = 2.2; *Dampftemperatur* = steam temperature; *Druck in ata* = pressure in atmospheres absolute; *Speisewassertemperatur* = feedwater temperature.)

steam to be circulated (and hence the energy of circulation) and the pressure and temperature of the superheated steam.

Apart from the circulating pump, which is often considered to be a nuisance feature of the Loeffler boiler, the directly fired superheater in that boiler is often considered as a weak or even dangerous part thereof. Because of the fact that even in conventional boilers where the superheater tubes are exposed only to comparatively mild temperatures the burning through of tubes is not infrequent, the conclusion has been drawn that in the Loeffler boiler, where the superheater is located in the region of the highest temperatures, there will be so much more of this kind of trouble. Those who think so, however, do not consider sufficiently the fact that in the Loeffler boiler the superheater has to handle many times the amount of steam that the superheater of a conventional boiler does, and furthermore that the velocity

of steam flow in the superheater tubes has been so selected that without unduly increasing the work of the circulating pump the heat transfer between the pipe wall and the steam is unusually favorable, while the ability of highly compressed saturated steam to take up heat is many times greater than is commonly assumed. In other words the cooling action of the superheated steam handled under these conditions is a very material one. In fact, the conditions of operation of the superheater are such that the superheater tubes can be made of material easily obtainable and not unreasonably expensive.

In a boiler generating 50,000 kg. (110,000 lb.) of steam per hour with the degree of feedwater preheating stated above, the weight of the steam that has to be circulated per hour is 160,000 kg. (353,739 lb.) and its volume about 2000 cu. m. (70,629 cu. ft.). This steam has to be brought to a temperature of 400 deg. cent. (752 deg. fahr.) in the radiant-type superheater. The heat that must be conveyed to the steam is about 16,000,000 kg-cal. per hr. According to Nusselt and Gröber, the heat transfer from walls of superheaters to superheated steam depends on the steam pressure, the steam temperature, the length of the superheater tube coil, the inside diameter of the superheater tubes, the velocity of steam flow, and certain physical constants of the steam. This is expressed in a formula in the original article from which it is deduced that the coefficient of heat transfer from the wall of the pipe to the superheated steam flowing through the pipe is $\alpha = 3265$ kg-cal. (1 cal. = 3.968 B.t.u.), with the dimensions of the heating surfaces of the superheater required in this case, namely, 76 sq. m. (818 sq. ft.) and the given tube diameters (I.D., 39.5 mm. = 1.554 in.; O.D., 51 mm. = 2.007 in.). The greatest temperature difference between the pipe wall and steam must be 65 deg. cent. (149 deg. fahr.). The transfer of heat through the walls requires a temperature difference of about 40 deg. cent. (104 deg. fahr.), so that the highest temperature on the inside of the pipe is 465 deg. and the highest temperature on the outside of the pipe, 505 deg. Because of the radiation of the above amount of heat, the flame temperature prevailing in the combustion chamber of the pulverized-coal furnace may be expected to be around 1250 deg. cent. (2282 deg. fahr.).

The greatest tensile stress occurring at the inside wall of the pipe is produced by the internal pressure, and has been found by calculation to amount to 505 kg. per sq. cm. (7181 lb. per sq. in.). There is also a tensile stress induced by the difference between the temperatures of the inner and the outer walls of the pipe and amounting to 560 kg. per sq. cm. (7963 lb. per sq. in.) so that the maximum total stress is around 1100 kg. per sq. cm. (15,642 lb. per sq. in.). The author gives in the original paper a series of curves for the heat-transfer coefficient for the flow of heat from the wall of the pipe to the superheated steam, and from this can be calculated the stresses for other cases.

The above-mentioned temperature and stresses do not represent anything extraordinary, and, as the paper shows elsewhere, can be handled with safety. As regards the material for the superheater tubes, it must satisfy the condition that at the above temperatures it should possess a creep strength considerably above the stress to which the pipe is exposed, and further it should not corrode under the existing conditions. There are already special steels available at a reasonable price to satisfy these requirements, in particular, molybdenum steels which at temperatures of 550 to 600 deg. cent. (1022–1112 deg. fahr.) possess a creep strength of 2000 to 4000 kg. per sq. cm. (28,440 to 56,880 lb. per sq. in.) and are non-corrodible up to 800 deg. cent. (1472 deg. fahr.). Observation of the behavior of superheater tubes in three Loeffler boilers now in operation confirm the above view. The conditions in the secondary superheater in which the steam is brought to the desired final temperature do not differ from those prevailing in superheaters of the conventional radiant boilers.

The evaporating drum has been specially designed by Loeffler and can be built from standard materials. The shell is formed out of the solid by turning or piercing and heavy heads are screwed in and beaded over, the walls of the drum being relieved from stresses by shrunk-on rings. The pipes for the admission of heating steam and feedwater and for the conveyance of saturated steam, as well as those for the water level gages, are brought in through the drum heads, with the result that, contrary to the practice in water-tube boilers, the walls of the evaporating drum are not weakened by drilling holes for the pipes. As the drum can be located anywhere outside of the boiler and is always outside the furnace, it is subjected only to saturated-steam temperatures, which means temperatures of about 330 deg. cent. (626 deg. fahr.).

The evaporating drum, of 1100 to 1200 mm. (43.4 to 47.2 in.) inside diameter, has walls from 75 to 80 mm. (2.95 to 3.14 in.) thick. This corresponds to a maximum tangential tensile stress of about 950 to 1000 kg. per sq. cm. (14,223 lb. per sq. in.) which at the prevailing temperatures does not call for anything beyond common structural materials. A water-tube boiler for the same temperature and pressure but with numerous holes drilled in its shell would have to have a wall 115 mm. (4.52 in.) thick.

From this the author proceeds to the consideration of factors determining the length of the drum. Among these, of practical interest is the storage capacity of the boiler as governed by consideration of its behavior in case of changes of load.

When demands on the boiler increase, the sensitive regulators installed on every boiler must accelerate the motors, pumps, and other masses before they can attain the speeds necessary to meet the new demands. It is unavoidable that the circulation pumps in the course of an increase of load from D to D_1 kg. per hr. should continue to circulate the amount of steam 3.5 D corresponding to the state of load of D kg. per hr. on the boiler, with the result that the amount of steam entering the evaporating drum is no longer 2.2 D but 3.2 $D - D_1$ kg. per hr., which means that it is less than previously, while at the same time 3.2 D kg. per hr., or a volume of saturated steam corresponding thereto, is taken away. The result is that, as in the case of any boiler in which the supply of heat and the discharging of steam are no longer in equilibrium, a fall of pressure takes place which is the greater the smaller the water content of the evaporating drum. When the suction volume of the circulation pump remains the same, this is accompanied by further reduction of the amount of steam produced and a further fall of pressure, which continues until the governing cycle is completed. Moreover the fall of pressure, which is a practically massless process, takes place more rapidly than does the setting into operation of the various governing devices. On the other hand, it should not be forgotten that evaporating drums represent a comparatively expensive storage space, and furthermore that the presence of a large supply of water delays the starting up of the boiler, in the course of which the water in it must be raised to the proper pressure and temperature. Wherever possible, therefore, an attempt will be made to maintain storage in the low-pressure range, and reduce as much as possible the variations of steam demand on the boiler. The author gives detailed figures illustrating this and comes to the conclusion that a boiler with an output of 50,000 kg. (110,231 lb.) of steam per hour needs two evaporating drums with a total storage capacity of 2500 kg. (5511 lb.).

Actually the storage capacity of Loeffler boilers is greater than an ordinary calculation would indicate, because, unlike the conventional medium- or low-pressure storage devices with their thin steel walls, in the Loeffler boiler the heat-storage capacity of the metal masses of the evaporating drums must not be left out of account. In the case which the author considers the heat content of the two drums, each weighing some 30,000 kg. (66,138

lb.) at 329 deg. cent. (624.2 deg. fahr.), is about 2,500,000 kg-cal., while the storage capacity of the water in the drums is only 2,100,000 kg-cal. During the evaporation of the water in the drum the heat content in the metal masses passes into the water in accordance with the fall of temperature of the latter, with the result that within the same pressure limits the water can generate more steam than would have happened with a practically adiabatic fall of pressure, i.e., in the case when the steam formation is controlled exclusively by the water content. In the case discussed by the author the amount of steam produced by the evaporating drum is actually practically double that which would be produced from the heat of water alone.

With the circulating pump at rest, if the firing be interrupted either by cutting off the supply of fuel in the case of pulverized-coal or gas firing or closing the air chamber in the case of stoker firing, the steam blowing off carries with it essentially only the amounts of heat stored up in the brickwork of the firing chamber and radiated to the superheater tubes. A very rapid cooling of the brickwork takes place, and even at a very low pressure the velocity of flow and the cooling action of the steam are sufficient to take up the heat flowing over the superheater tubes.

The two vessels together have a water surface giving off steam of 21 sq. m. (225.04 sq. ft.) and a steam space of 9 cu. m. (317.83 cu. ft.). The load on the water surface giving off the steam is, therefore, 7600 kg. per sq. m. per hr. (108,072 lb. per sq. ft. per hr.) or 100 cu. m. per sq. m. per hr. (328 cu. ft. per sq. ft. per hr.) and the load on the steam space is about 2100 cu. m. per cu. m. per hr. (6892 cu. ft. per cu. ft. per hr.).

All of these figures are (even where the feedwater is dirty) much lower than those accepted as permissible, and constitute a guarantee that neither water nor any of its constituents will be carried over into the superheater.

Starting of the plant from cold, i.e., for the first time or after any considerable rest period sufficient to let the boiler cool down completely, is effected by supplying to the evaporating drum steam or hot water or by supplying the circulating pump with steam from another boiler unit or from an auxiliary boiler.

The auxiliary steam is delivered to the evaporating drum through a special pipe, as the introduction of steam direct into the steam space has the disadvantage of producing irregular distribution of temperature in the evaporator drum which causes temperature stresses and delays steam formation. Up to the time when the temperature of the mass of water reaches about 80 deg. cent. (176 deg. fahr.) the admission of the auxiliary steam into water must be effected carefully, as otherwise vigorous condensation processes take place and may give rise to water hammer in the water space.

A simpler method is to fill the evaporating drum with hot water from the start up to a level above that of the pipe through which the auxiliary steam is admitted, and only then start up the circulating pump and the firing. Then, if necessary, the water may be further heated by admission of steam, which at higher temperatures, can be done rapidly.

Under such conditions the starting up of the boiler is somewhat like that of a direct-current electric generator. However, instead of a residual magnetism we have the heat content of the mass of water which gives up steam first, as a result of the fall of pressure, and then as a result of the supply of heat from the superheater taking place under the corresponding increase of temperature and pressure. As compared with the use of auxiliary steam for initial heating, this method has the advantage that the water level in the evaporating drum changes but little.

In any event, starting is delayed through the fact that at the beginning a very considerable amount of condensation takes place in the cold superheater tubes and the remainder of the piping. At Witkowitz with the 15-ton Loeffler boiler it was found that at the start from cold, steam is given up for a period of 1 to 3 hr.; the normal output of the boiler is reached only after about $4^1/_4$ hr., and the desired temperature of 460 deg. cent. (860 deg. fahr.) only from 2 to $4^1/_2$ hr. after the beginning of the evolution of the steam. In later boilers these periods of time have been considerably decreased by the installation of means for dewatering the superheater coils and of certain other devices.

If, after having been operated for any length of time, the boiler is idle for a short period, enough heat is retained in the water mass of the evaporator drum to permit starting without auxiliary steam.

One of the most important features of high-pressure work in general, and of the Loeffler boiler in particular, is the quantity question. One can describe it by saying that, in so far as the application to steam turbines is concerned, the high pressure presupposes, in order to make use of its advantages, work on a very large scale. This is due to the fact that even very large weights of steam are here represented by very small steam volumes, so that even high-pressure turbines of very considerable steam consumption have in their high-pressure stages blade dimensions which are too small to be economical, and that the ratio of the actual steam cross-section and clearance cross-section is unfavorable. The result of this is a reduction in efficiency of the small high-pressure turbines, which has been greatly underestimated.

An investigation conducted on Ljungström turbines with different steam pressures and turbines has shown that the smallest quantities of steam which permit the use of blade length that can be economically built, together with reasonable efficiencies, are such as those shown in Figs. 2 and 3. These graphs show that at 100 atmos. gage pressure and 450 deg. cent. (842 deg. fahr.) ahead of the turbine in the case of Ljungström back-pressure turbines, the amount of steam that can be put through per hour should not be below 40,000 kg. (88,184 lb.), while in the Ljungström condensing turbine it should not go below 29,000 kg. (63,933 lb.); and it should be remembered that in the case of the Ljungström turbine the situation is particularly favorable, because in that turbine the blade lengths and cross-sections are favorable even for small volumes of steam, because of the small diameters of its high-pressure stages.

The fact that the condensing-type turbine can manage smaller amounts of steam is due to the circumstance that, unlike the back-pressure turbine with its ability to handle up to 40,000 kg. of steam, the condensing-type turbine can compensate its somewhat poorer efficiency in the high-pressure stage by the performance of its low-pressure stages. An improvement in existing conditions can be achieved through the fact that in the Loeffler boiler, because of the small amount of the work used in circulation, steam may be produced at pressures of 120 to 130 atmos. and corresponding temperatures, and the pressure can then be reduced previous to the admission of the steam into the turbine. By these means an increase of the volume of steam handled by the turbine and an improvement of the efficiency is obtained equivalent to an extension of the range of application of the boiler as determined by purely technological considerations. The reciprocating steam engine is much less suitable for handling small volumes of steam, as in that case its lower limit of capacity lies at about 8000 kg. (17,636 lb.) per hr.

While the above restrictions of the use of high-pressure steam apply generally, i.e., without regard to the type of boiler, in the Loeffler boiler one must further consider the relation between the circulating pump and the magnitude of the boiler output, since the latter determines whether the pump should be of a reciprocating type or rotary type.

As indicated by Fig. 1 and the explanations given above, the volume of steam that has to be circulated under otherwise similar conditions is the smaller the higher the pressure. For example,

at a steam temperature of 500 deg. cent. (932 deg. fahr.) and feedwater temperature of 240 deg. cent. (464 deg. fahr.), the following figures apply for an output of steam of 10,000 kg. (22,046 lb.) per hr.

100	120	130	140	atmos.
636	462	405	361	cu. m. per hr.
0.177	0.128	0.113	0.10	cu. m. per sec.

From these it would appear that even for considerable outputs of the boiler the volume of the steam remains small. These

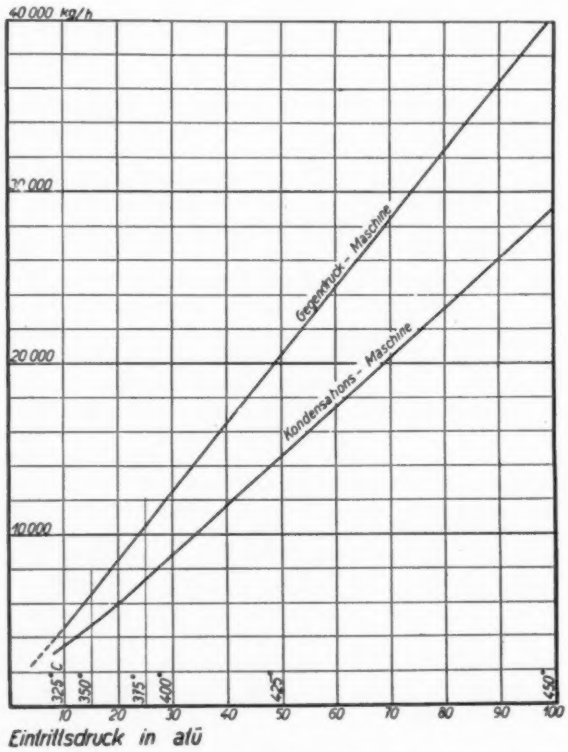


FIG. 2 MINIMUM AMOUNT OF STEAM HANDLED BY LJUNGSTRÖM TURBINES FOR VARIOUS INITIAL PRESSURES

(*Kg/h* = kg. per hr.; *Gegendruck-Maschine* = back-pressure turbine; *Kondensations-Maschine* = condensing-type turbine; *Eintrittsdruck in atü* = initial pressure in atmospheres, gage.)

volumes of steam furthermore have been calculated for the normal load of the boiler working against a resistance of about 3 atmos; for a continuous output of 20 per cent more the delivery was against a pressure of 4 to 4.3 atmos. From this the following figures have been calculated for the above case for the value of the theoretical work consumed in circulation.

100	120	130	140	atmos.
70.5	51	45	40	normal hp.
113	82	72	64	maximum hp.
1.57	1.14	1	0.89	

The actual work consumed in circulation depends on the design of the circulating pump and the machine that is driving it. The author discusses these two elements.

The author next considers the case of a boiler that has to handle a volume of steam of 0.575 cu. m. (20.303 cu. ft.) per second, and finds that the theoretical work consumed in circulation is 230 hp., while the actual work in the case of a rotary circulating pump is dependent on the type of drive employed and varies from 390 to 410 hp. or from 260 to 273 kw. These figures agree with a rule-of-thumb in accordance with which the power consumed in circulation, depending on the kind and size of the circulating pump and the drive employed, is from 5 to 7.5 kw. per ton (metric ton = 1000 kg. = 2204.6 lb.) of output of boiler. Another way of estimating can be obtained by basing the power consumed in circulation on the output of a condensing turbine supplied by steam from the boiler. The latter in this case is 13,000 kw., and the work of circulation is about 2 per cent.

From this the author proceeds to consider the power consumption of the feedwater pump. In the Loeffler boiler as compared with other types of high-pressure boilers, the feedwater pump need not be very much greater in capacity than what corresponds to the steam generation of the boiler; while in other boilers, as the author states, the feed pump must be capable of handling an amount twice as great as the normal boiler output.

This, he claims, leads to a continuous underloading of the boiler-feed pump under normal operating conditions, resulting in a reduced efficiency of the pump. The original article contains a set of curves showing the power consumption of the circulating and feedwater pumps. This is not reproduced because of lack of space. The next subject considered by the author is the application of the boiler. In this connection he considers the case of a cellulose and paper factory with two turbines—one a bleeder back-pressure turbine generating the steam required for cooking and drying, and other a pure condensing turbine producing the steam required to balance output of 18,000 to 20,000 kw. The arrangement is such as shown in Fig. 4 with a Loeffler

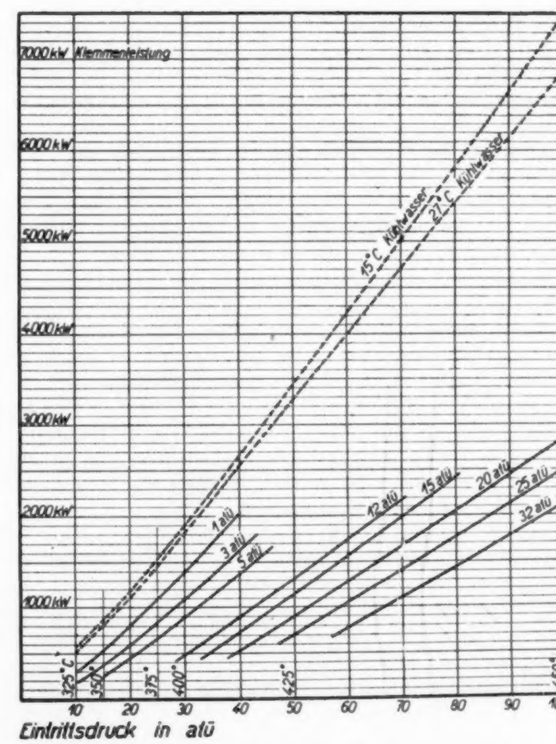


FIG. 3 MINIMUM OUTPUTS OF LJUNGSTRÖM TURBINES FOR VARIOUS INITIAL AND BACK PRESSURES

(*Klemmenleistung* = output at bus bars; *kühlwasser* = cooling water; *atü* = atmospheres, gage; *Eintrittsdruck in atü* = initial pressure in atmospheres, gage.)

high-pressure unit set ahead of a unit working with a pressure of 18 atmos. For the sake of simplicity the steam piping has been left out of the diagram and furthermore the fact has been neglected that in a plant of this kind it is proper to employ a Ruths accumulator. Had this accumulator been installed, the best

place for it would have been in parallel with the piping used for cooking and heating.

The steam required for power purposes generally and for driving the turbine operating the Loeffler circulating pumps first flows through an advance turbine, which it enters with a pressure of 21 atmos. and 250 deg. cent. (428 deg. fahr.) and leaves with a pressure of 21 atmos. and 250 deg. cent. (482 deg. fahr.). In this turbine an output of 12,600 kw. is produced, which is used for supplying power to a neighboring mill. The steam leaving this turbine before going to the other power machinery is passed through an intermediate superheater heated by condensing live steam and is brought there to a temperature of 350 deg. cent. (662 deg. fahr.) and 18 atmos. pressure. Distribution of heat in the plant is shown in Fig. 5, from which, among other things, it appears that the exhaust steam from the turbine driving the circulating pump is used for preheating the feedwater and, if necessary, for general heating purposes.

While the value of high-pressure steam in many other applications has been generally quite well recognized, its economy for straight power generation in condensing turbines is still in doubt. It is therefore of interest to see on the basis of carefully worked-out layouts how

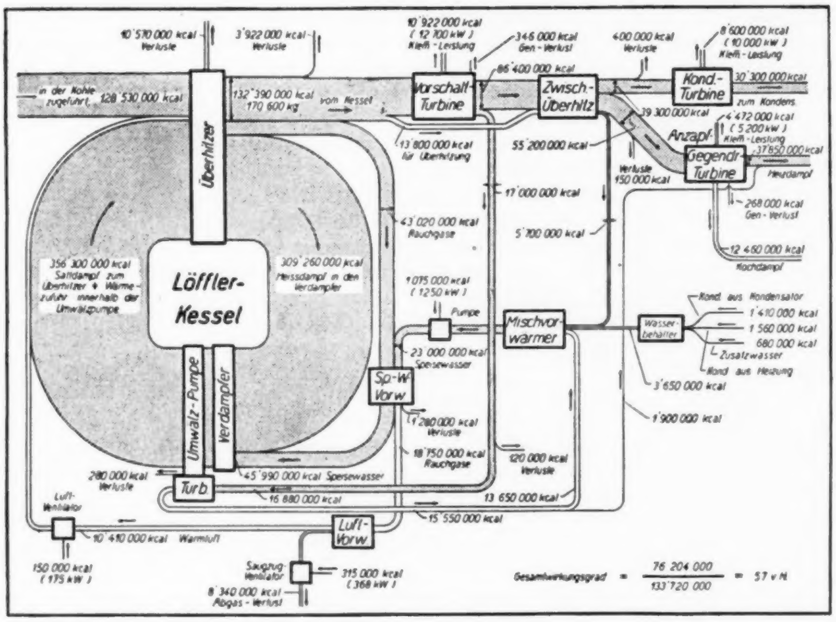


FIG. 5 HEAT FLOW IN A PAPER MILL EQUIPPED WITH A LOEFFLER SUPER HIGH-PRESSURE BOILER

(*Verluste* = losses; *Klemm-Leistung* = output at the bus-bars; *In der Kohle zugeführt* = brought in the coal; *vom Kessel* = from the boiler; *Vorschaltturbine* = advance turbine; *Zwisch. Überhitzer* = intermediate superheater; *Kond. Turbine* = condensing turbine; *Zum Kondens.* = to the condenser; *Anzapf-Gegender* turbine = bleeder back-pressure turbine; *Heizdampf* = steam for heating; *Kochdampf* = steam for cooking; *Rauchgase* = flue gases; *Sattdampf zum Überhitzer + Warme zufuhr innerhalt der Umwälzpumpe* = saturated steam for the superheater + heat supply within the circulating pump; *Heissdampf in dem Verdampfer* = live steam in the evaporator; *Umwälzpumpe* = circulating pump; *Verdampfer* = evaporator; *Mischvorwärmer* = mixing preheater; *Wasserbehalter* = water tank; *Kond. aus condensator* = condensate from the condenser; *Zusatzwasser* = make-up water; *Kond. aus Heizung* = condensate from the heating system; *Sp-W-Vorw.* = feedwater preheater; *Speisewasser* = feedwater; *Luft* = air; *Warmluft* = warm air; *Luftvorw.* = air preheater; *Abgas* = exhaust gas; *Gesamtwirkungsgrad* = total efficiency.)

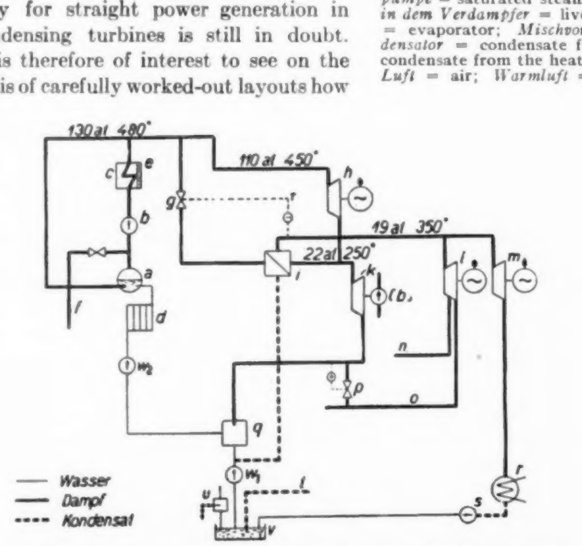


FIG. 4 LAYOUT OF A LOEFFLER HIGH-PRESSURE UNIT IN A PAPER MILL

(*at* = atmospheres absolute; *Wasser* = water; *Dampf* = steam; *Kondensat* = water of condensation; *a-e Löffler-Höchstdruckkessel* = Loeffler high-pressure boiler; *a*, *Verdampfertrommel* = evaporating drum; *b*, *Dampfumwälzpumpe* = steam-circulation pump; *c*, *Überhitzer* = superheater; *d*, *Rauchgasvorwärmer* = economizer; *e*, *Luftvorwärmer* = air preheater; *f*, *Anfahrdampf* = steam for starting; *g*, *Temperatur-Regelventil* = temperature-regulating valve; *h*, *Hochdruck-Vorschaltturbine* = high-pressure advance turbine; *i*, *Dampf-Dampfüberhitzer* = steam-operated steam superheater; *k*, *Hilfsturbine zum Antrieb der Dampfumwälzpumpe b* = auxiliary turbine for driving steam-circulating pump *b*; *l Anazapf-Gegendruck-Turbine* = bleeder back-pressure turbine; *m*, *Kondensat-Turbine* (*corhanden*) = condensing turbine; *n*, *Kochdampf* = cooking steam; *o*, *Heizdampf* = heating steam; *p*, *Überströmventil* = overflow valve; *q*, *Mischvorwärmer* = mixing preheater; *r*, *Kondensator* = condenser; *s*, *Kondensatpumpe* = condenser pump; *t*, *Kondensat aus Heizdampf* = condensate from heating steam; *u*, *Wasserreiniger* = water purifier; *v*, *Speisewasserbehälter* = feedwater tank; w_1, w_2, *Speisewasserpumpen* = feedwater pumps.)

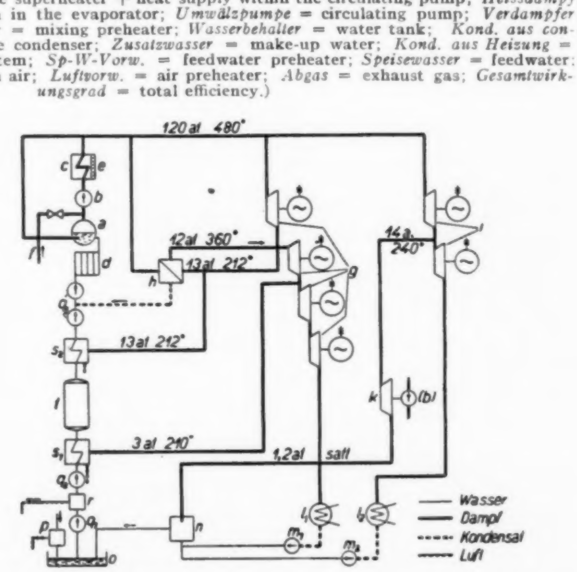


FIG. 6 LAYOUT OF A LOEFFLER HIGH-PRESSURE UNIT IN A LARGE CENTRAL STATION

(*at* = atmospheres; *Wasser* = water; *Dampf* = steam; *Kondensat* = water of condensation; *Luft* = air; *a-e Löffler Höchstdruckkessel* = Loeffler high-pressure boiler; *a*, *Verdampfertrommel* = evaporating drum; *b*, *Dampfumwälzpumpe* = steam circulation pump; *c*, *Überhitzer* = superheater; *d*, *Rauchgasvorwärmer* = economizer; *e*, *Luftvorwärmer* = air preheater; *f*, *Anfahrdampf* = steam for starting; *g*, 3 *Hauptturbinen* = 3 main turbines; *h*, *Dampf-Dampfüberhitzer* = steam-operated steam superheater; *i*, 2 *Hausturbinen* = 2 house turbines; *k*, *Hilfsturbine zum Antrieb der Dampfumwälzpumpe b* = auxiliary turbine for driving the steam-circulating pump *b*; l_1, l_2, *Kondensatoren* = condensers; m_1, m_2, *Kondensatpumpen* = condensate pumps; *n*, *Mischvorwärme* = mixing preheater; *o*, *Speisewasserbehälter* = feedwater tank; *p*, *Wasserreiniger* = water purifier; $q_1 - q_3$, *Speisewasserpumpen* = feedwater pumps; *r*, *Luftabscheider* = air seperator; s_1, s_2, *Speisewasservorwärmer* = feedwater preheater; *t*, *Speisewasserspeicher* = feedwater accumulator.)

the high-pressure plant of a given output compares from the point of price and economy with medium- and low-pressure plants. The comparison is here made on the basis of a large central station of 75,000 to 90,000 kw. total output, which in the case of a Loeffler boiler, is laid out as shown in Fig. 6, and using steam of a pressure of 130 atmos. and 500 deg. cent. (932 deg. fahr.) temperature. The plants with which the Loeffler boiler is compared operate with steam at 40 atmos. and 450 deg. cent. (842 deg. fahr.) on one hand and 25 atmos. and 400 deg. cent. (752 deg. fahr.) in another case. In all three cases pulverized-coal firing is assumed to be provided, and the plants are supposed to be operated at their maximum respective economies.

The calculation of the consumption of heat in the three cases at full load on the assumption of a boiler efficiency of 85 per cent gives the following figures:

High-pressure plant.....	3080 kg-cal. per kw-hr.	0.86	0.91
Medium-pressure plant..	3390 kg-cal. per kw-hr.	0.95	1
Low-pressure plant......	3570 kg-cal. per kw-hr.	1	1.05

In these figures of heat consumption the power consumption of the various auxiliaries (condensers for the three main turbines and an auxiliary turbine, circulating and feedwater pumps, preparation of the powdered fuel, suction fans, blowers, coal-handling plant, electric power for stack-gas purification, lighting) is estimated at 7.1 per cent of the total current generated in normal operation in the case of the Loeffler high-pressure boiler, and at

TABLE 1 RELATIVE COSTS

Operating pressure....................at.	25	40	130
Operating temperature...........deg. cent.	400	450	480
Number and dimensions of the main turbines..........................kw.	3 × 25,000		
Number and dimensions of the house turbines..........................kw.	2 × 8,000		
Number and type of boilers...............	3 + 1 inclined-tube, 3 drum boilers		3 + 1 Loeffler
	(1 boiler in reserve)		
Heating surface or output per boiler.......	2600 sq. m.	2400 sq. m.	130 tons per hr.
Necessary output of the pulverized-coal firing plant in tons per hour............	75	66	60
Initial Costs:			
Boiler plant complete, including feedwater pumps..............................	1	1.06	0.995
Complete installation for handling and preparation of coal, not including buildings..............................	1	0.95	0.94
Buildings, complete.....................	1	1	0.915
Water preparation......................	1	0.965	0.61
Prime movers..........................	1	1.01	1.025
Total plant cost.......................	1	1.02	0.995
Costs of operation:			
Cost of fuel...........................	1	0.945	0.885
Total cost of operation.................	1	0.975	0.93

6 per cent for the other two types of plant. At smaller loads the figures for heat consumption for the auxiliaries increase, but their ratio remains practically the same. In this connection attention is called to Table 1, which would indicate that for a plant of the size specified above the Loeffler boiler plant costs no more than the boiler of a plant working at 25 atmos. pressure, and costs about 7 per cent less than the one working at 40 atmos. pressure. Of particular interest is the difference in favor of the high-pressure boiler with respect to fuel and general costs of operation, as these seem to justify the employment of the Loeffler boiler for pure power generation. The figures given for the cost of the building call attention to the fact that the Loeffler boiler is a type which is very economical with respect to floor space occupied, which may be brought down to as low as 1.65 sq. m. (17.75 sq. ft.) per ton of steam generated per hour. (Dr. of Engrg., F. Englert, Nuremberg Works of the M.A.N., in *Mitteilungen aus den Forschungsanstalten*, vol. 1, no. 4, April, 1931, pp. 69–79, 9 figs., *etA*)

Short Abstracts of the Month

CORROSION

Products of Corrosion of Steel

THE composition and uniformity of the products formed in the corrosion of steel in oxygenated water are shown to be important factors in determining the ultimate rate of corrosion. As regards the mechanism of corrosion, the authors state that the electrochemical theory of corrosion affords only a starting point.

In its generally accepted form the theory postulates the dissolution of a metal with the formation of a positively charged metal ion and the simultaneous displacement of hydrogen ions from the solution. Furthermore, the points at which the metal goes into solution are assumed to be at finite distances from the points at which the hydrogen ions are deposited. Corrosion proceeds because of the removal of hydrogen from the metal surface by reaction with dissolved oxygen. The rate of corrosion in water containing dissolved oxygen is therefore dependent upon the speed with which oxygen reaches the metal surface, and consequently upon the oxygen concentration and the resistance to diffusion offered by the liquid and the corrosion product films. This theory considers only the initial and final states, and is not concerned with the factors influencing the diffusion resistance of films.

In the opinion of the authors, the observed facts cannot be explained by the electrochemical theory alone, and they offer another explanation of the phenomena. They claim that the hydrogen-ion concentration is different at different portions of the liquid film near the metal; hence different corrosion products may be expected, which may in turn influence the corrosion rates. This may be further affected by agitation of the liquid, and in addition the ferrous ions will be oxidized by the dissolved oxygen to ferric ions. In the event of the outward diffusion of these ions into the liquid, there will probably result the precipitation to ferric hydroxide, since this can be precipitated at a much lower pH than ferrous hydroxide. If, however, for any reason both ferrous and ferric hydroxide are precipitated, as may be the case when the solution is quiescent (or moving slowly) a reaction may take place between these two hydroxides to form the magnetic oxide of iron, which has a physical structure markedly different from that of the hydroxides. This picture of the mechanism of film formation apparently affords a satisfactory explanation of the phenomena observed during the experiment.

The author comes to the following conclusions:

The ultimate rate of corrosion of iron in oxygenated water is dependent largely upon the character, composition, and thickness of the corrosion film.

The composition of the film is dependent upon the pH of the liquid near the metal surface and the uniformity of ionic concentrations of the liquid film on the metal surface.

The product formed in the submerged corrosion of iron in oxygenated distilled water is composed largely of the magnetic oxide of iron when the diffusion of ions from the liquid film to the main body of the solution proceeds slowly or non-uniformly.

The corrosion product formed under conditions of uniform and rapid ionic diffusion from the liquid film is composed largely of gelatinous ferric hydroxide.

The granular magnetic oxide formed is not very resistant to the diffusion of the various ions or of oxygen.

The gelatinous ferric hydroxide greatly retards the diffusion

of oxygen and ions, and thus prevents the formation of high concentrations of hydroxyl ions at the metal surface and the subsequent formation of non-resistant films. (H. O. Forrest, B. E. Roetheli, and R. H. Brown, Department of Chemical Engineering, Mass. Inst. of Technology, Cambridge, Mass., in *Industrial and Engineering Chemistry*, vol. 23, no. 6, June, 1931, pp. 650–653, 4 figs., and a brief bibliography, *t*)

ENGINEERING MATERIALS

Trend of Progress in Great Britain on the Engineering Use of Metals at Elevated Temperatures

ONLY a partial abstract of this interesting paper can be given here because of lack of space.

Much thought and time have been expended in Great Britain during the past few years in developing new forms of "accelerated" creep tests intended to produce in a short time the same indications regarding the fitness of material as must occupy very long periods when tests are made by the more fundamental long-duration method. Among such methods which are now being thoroughly tried out are the time-yield method introduced by Hatfield, and the method devised by Barr and Bardgett, which latter depends on the accurate measurement of the diminishing rate of creep in a specimen initially subjected to a maximum commencing load, measured by means of a steel weight bar, so that the rate of decrease of the applied stress is proportional to the extension of the heated test specimen.

The authors give specifications for steel that can be used in parts subjected to high-pressure elevated temperatures and possibly chemical reactions, and give a table showing the strength of certain alloy steels of indicated chemical composition.

It has been found that of the alloy steels in general use, the creep properties of nickel-chromium steel containing 3 to 3.5 per cent nickel and about 1 per cent chromium are disappointingly low and are little, if any, superior to a good mild steel at temperatures between 400 and 500 deg. cent. (750 and 930 deg. fahr.) and that the nickel content can be very considerably reduced without any apparent disadvantage. Indeed it becomes very doubtful whether nickel is of any value in improving the load-carrying ability of this type of steel at elevated temperatures. Of the low-alloy content steels, chromium-vanadium steel (1 per cent chromium, 0.25 per cent vanadium) has been found to be very satisfactory up to 400 deg. cent. (750 deg. fahr.), but its strength drops off very rapidly beyond this temperature. Nickel-chromium-molybdenum steel, of an average composition of 2.5 per cent nickel, 0.7 per cent chromium, 0.30 per cent molybdenum, has excellent properties up to 500 deg. cent. (930 deg. fahr.), but practically all of the steels of this class creep very rapidly under stresses of the order of 3000 lb. per sq. in. at 550 deg. cent. (1020 deg. fahr.)

On the other hand, it is definitely proved that the addition of molybdenum without nickel or chromium very greatly improves the strength at high temperatures, particularly in the range 400 to 500 deg. cent. (750 to 930 deg. fahr.) In consequence of this, much work has recently been carried out on low-carbon molybdenum steels containing about 0.10 to 0.20 per cent carbon and 0.30 to 0.40 per cent molybdenum. This steel presents no special manufacturing difficulties, and can be forge-welded, oxyacetylene welded, and electrically welded. It has remarkably high creep properties at temperatures up to 550 deg. cent. (1020 deg. fahr.) and is definitely superior in this respect to many of the more expensive and less easily produced alloy steels. Its extended use for steam-power-plant components and chemical vessels can be confidently anticipated.

While nickel does not seem to be beneficial in increasing strength at high temperatures, increases in chromium content definitely result in improved creep properties. A steel containing 8 per cent of chromium and 3 per cent of silicon has good creep strength up to 500 deg. cent. (930 deg. fahr.) and has been largely used for valves operating at high temperatures, but extension to other fields of application is likely to be limited owing to difficulties in manufacture. Increasing the chromium content to 12 per cent and upward leads to the "martensitic stainless" class of steels which possess not only excellent creep properties but also considerable resistance to oxidation at high temperatures. Quite apart from their use at ordinary temperatures for corrosion-resistance purposes, these steels are successfully used in the chemical industry for valve parts in plants operating at high temperatures and pressures, where resistance to erosion and corrosion, and the maintenance of shape and dimensions are all essential.

While pearlitic alloy steels have sufficiently good creep properties for many applications involving stress and temperature, care must be taken to avoid steels likely to suffer from embrittlement in service. This is particularly important in connection with vessels and plant parts under stress which are heated up to operating temperature and cooled down very many times in their life. Some experiments were recently made to determine the effect of such cycles of temperature on various steels while under stress of 11,000 to 22,000 lb. per sq. in. and a table [II] in the original paper shows the effect on the Izod impact-test results of 50 heatings to, and coolings from, 390 deg. cent. (730 deg. fahr.) and 450 deg. cent. (840 deg. fahr.). It is shown that this has caused very severe embrittlement in certain cases, but not in others. It seems clear that the presence of nickel increases the liability to embrittlement, while the presence of molybdenum, in sufficient quantity, has a markedly beneficial effect.

The action of gases is discussed next, as well as the matter of temperatures which various steels can stand. Mild steel possesses a sufficient resistance to oxidation for most practical purposes at temperatures up to 500 deg. cent. (930 deg. cent.) when the rate of loss by scaling reaches about 0.001 gr. per sq. in. per hr. The expensive heat-resistant materials are, in this respect, suitable for use up to 900 or 1000 deg. cent. (1650 to 1830 deg. fahr.), but a demand has arisen for a moderately priced material for this range. This need is being met by a steel which is presenting no special manufacturing problems and one which can be drawn into tubes; it contains essentially $7^1/_2$ per cent of chromium and 0.05 to 1 per cent of silicon, with a low carbon content, usually less than 0.12 per cent. This steel offers excellent resistance to oxidation up to 700 deg. cent. (1290 deg. fahr.), above which it is necessary to resort to the generally used heat-resistant alloy steels.

Less expensive steels are receiving much attention; for example, steels of a 30 per cent chromium type are successfully used as castings where scaling resistance is of primary importance and no great strength is required. By suitably modifying the composition, this material can be rolled into plates or sheets down to No. 20 gage, and proves very useful for parts which may be built up from welded or riveted plates. When compared with the high-nickel-chromium-iron alloys, the 30 per cent chromium steel has an almost equal resistance to oxidation and is much more resistant to the action of sulphur gas. It is, however, relatively brittle in the cold condition.

The authors discuss next some factors arising in correct design, in particular the design of a part for operation at a particular temperature for which experience exists at lower temperature. This deals, among other things, with the subject of creep and the meaning of the term "limiting creep stress." This part, while very interesting, is not suitable for abstracting. (R. W. Bailey, H. S. Dickenson, N. P. Ingliss, and J. L. Pearson

in a *Symposium on Effect of Temperature on the Properties of Metals* issued jointly by the American Society for Testing Materials and The American Society of Mechanical Engineers, Chicago, June 23, 1931, pp. 136–154, 3 figs., *g*)

INTERNAL-COMBUSTION ENGINEERING

New Ideas on Carburetion

THE author does not approve of the atomizing type of carburetor, and suggests that instead of producing the gaseous state by the means used now, a carbureting gas should be used. He claims that it is easy to make such a gas, as in a cubic foot of air at ordinary temperature at 15 deg. cent. (59 deg. fahr.) and atmospheric pressure of 760 mm., 1.4 kg. (3.09 lb.) of gasoline can be vaporized at ordinary temperature per cubic meter (35.3 cu. ft.) of air. In this way a gaseous mixture carbureted to saturation is obtained; it is of a perfectly definite composition, and all that is necessary is to take two parts of this carbureted air and add to it 18 parts by weight of air to obtain the optimum proportion. Such a saturated gas presents certain advantages in that it is non-inflammable as its gasoline content greatly exceeds the rich limit of inflammability. It has the gasoline in concentrated form, as a cubic meter of explosive mixture need not contain more than 70 grams of gasoline. The margin in this case is therefore quite large, and heavier fuels may be used. At the same time this mixture is less concentrated than liquid gasoline, and is therefore easier to handle, while its density is approximately the same as that of air.

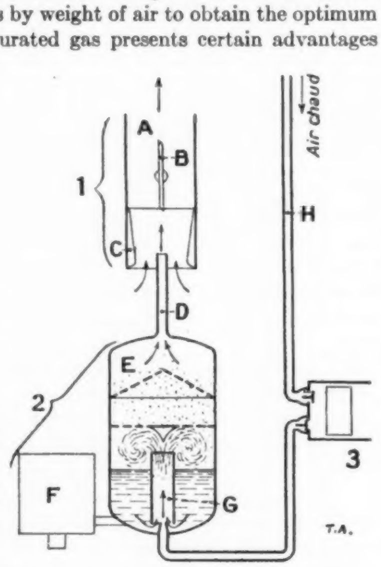


FIG. 1 DIAGRAMMATIC ARRANGEMENT OF A PREVAPORIZATION CARBURETOR
(*Air chaud* = hot air.)

As to the design of the apparatus, the author calls attention to a very simple solution based on the following arrangements: Atomization is obtained by a jet of air under a pressure of 500 to 1000 grams, no matter what the rate of operation of the engine may be. This pressure is greatly in excess of the vacuum created by suction, which reaches not more than 40 grams at the exit from the pipe and falls away to a few grams in the slower region. The latent heat of vaporization is provided by passing from air from 90 to 100 deg. cent. (194–212 deg. fahr.) along the suction pipe, so that after vaporization the carbureted gas is at room temperature. The apparatus itself, Fig. 1, consists of the carburetor 1, consisting of an extension of the admission pipe *A*, butterfly valve *B* regulating the quantity of explosive mixture admitted to the engine, and the constricted passage *C* for regulating the air admission.

Next there is a gasifier 2, consisting of a vessel *E* large enough to contain a volume of carbureted gas sufficient to feed the engine for several revolutions. This vessel in which the gas is formed receives liquid fuel from the constant level *F* and conveys the gas formed to the carburetor by means of the passage *D*. Partitions are provided on the inside of the gasifier, while the compressed air goes into the atomization tuyere *G*, the admission point of which is at the lowest point in the gasifier. The third part consists of a compressor driven in some way from the engine and compressing the air heated by a flow along the exhaust pipe through the tube provided with some means of regulation *H*.

As regards the operation of this device, the air is driven into the carburetor by the suction of the motor and its amount is regulated by the opening in vessel *C*. The compressor takes in hot air and delivers it to the tuyere *G* under pressure.

As the level of the fuel is above the admission point to the tuyere, the liquid penetrates into the lower part of the latter and is thrown out and atomized by the force of the air current. The jet then impinges on the partitions provided in *E* as stated before, so that not a single particle of liquid can arrive at the exit *D*. The gasoline vaporizes instantly under the influence of the intensive atomization and heat. The quantity of atomized gasoline does not need to be closely calibrated. It is merely necessary that it should be larger than needed.

On the other hand, the quantity of vaporized gasoline can never exceed the amount necessary for saturating the quantity of air coming from the condenser, as any excess above that recondenses and returns to the bottom of the receiver, to be taken up in due time by the tuyere. Because of the constant level, no more gasoline can be admitted than can be vaporized. Moreover, because of the fact that the liquid is taken by the tuyere at the lowest point in the gasifier there can be no fractional vaporization, and the elements in the fuel most difficult to vaporize are the first to be taken up. The quantity of vaporized gasoline depends solely on the quantity of air delivered by the compressor, and is therefore at all times proportional to the number of revolutions of the engine. Finally (and this is very important), instead of being taken up by suction the saturated gas in this case is forced through the tube *D* into the carburetor, which insures a more complete filling of the cylinders.

It is not stated in the original article whether or not such a carburetor has been built and if so what actual results were obtained with it in practice. (L. Durand in *La Technique Automobile et Aerienne*, vol. 22, no. 153, 2nd trimestre, 1931, pp. 55–57, 4 figs., *d*)

LUBRICATION

Synthetic Lubricants

THE chemists of the Standard Oil Company of Indiana have been working for several years to determine, first, what single hydrocarbon or combination of hydrocarbons makes the best possible lubricant, and second, whether such a lubricant can be made synthetically. It was found that the ideal lubricant would be made up of hydrocarbons having in their molecules approximately two hydrogen atoms for each carbon atom, and when such oils were made synthetically on a laboratory scale it was found that those oils having the carbon atoms arranged in long chains were much superior to those in which the carbon atoms were connected in the form of rings. In many natural oils these highly desirable hydrocarbons appear to be present in small proportions, but hitherto it has been impossible to separate them from the other hydrocarbons.

To produce this oil synthetically it was found that the most practical process was the polymerization of certain hydrocarbons known as olefines which had the desired composition of two atoms of hydrogen to one of carbon. Not all olefines but only a certain type of them gave good results, however, and olefines of that type were rare and expensive. A cheaper source of these hydrocarbons was therefore sought and found in paraffin wax. The wax, however, cannot be used in its original state. It has to be put through a chemical change by cracking methods similar to those which are used in producing gasoline. After being cracked under certain

conditions, paraffin wax yields the type of olefines needed, and these are then subjected to polymerization.

The new oils can be made in any desired viscosity. They have a pale straw color, high resistance to oxidation and sludging, very low pour test, and low volatility or evaporation tendency. Above all the new oil is more resistant to changes in temperature than any known natural oil. This property prevents its thinning and losing body at high temperature, and at the same time prevents excessive thickening in cold weather.

While the cost of the raw materials and the complicated operations involved in manufacture make these synthetic oils rather expensive, they are now being made commercially by the Standard of Indiana. (F. W. Sullivan, V. Voorhees, A. W. Neeley, and R. V. Shankland, Standard Oil Co. of Indiana, in a paper before the Indianapolis Meeting, 1931, of the American Chemical Society; abstracted through *World Petroleum*, vol. 2, no. 5, May, 1931, p. 336, *d;* see also *Industrial and Engineering Chemistry*, vol. 23, no. 6, June, 1931, pp. 604–611, 3 figs. and an extensive bibliography)

POWER-PLANT ENGINEERING

The Cleaning of Power-Station Waste Gases

THE matter of air pollution caused by boilers fired with pulverized fuel is attracting considerable attention at the present time. The article here abstracted describes methods and apparatus in use in several countries. The problem seems to have been solved technically, and what is now required is that it should be solved economically and that a method and apparatus should be standardized applicable to all dust-fired boilers, whatever their size or steaming capacity, at a reasonable cost. As a definition of reasonable cost the author gives the figure of 1 shilling (say, 24 cents) per ton of coal consumed, this charge to cover both capital amortization and running costs, including that for water.

The Pfleiderer System. This system has been installed in the power plants at the works of the Badische Anilin und Soda Fabrik at Oppau on the new high-pressure boiler unit installed in 1927. It has a heating surface of 21,500 sq. ft. and is fired with pulverized coal by the Lopulco system. Only a very restricted space was available when this boiler was erected, and it was therefore decided to adopt the double upright-tube design for the boiler, with the economizer and air heater superimposed upon it. This plan necessitated the erection of a boiler house 130 ft. high, and on account of this great height the chimney stacks only rise 20 ft. above it. The Pfleiderer system is a combination of a cyclone type of grit and dust separator with a gas washer of the sprinkler type, the two being operated together as one apparatus. The washer is mounted on the gas-exit side of an induced-draft fan, and the gases pass away directly from it into the short chimney stacks. An efficiency of 90 per cent is claimed for this system of gas cleaner. The unit consists of two similarly cylindrical chambers 12 ft. 6 in. in diameter and 8 ft. 6 in. deep from the cover to the valve by which they are emptied. A system of water-supply pipes is placed inside the cover of each of these chambers, and the whole of the interior of the washer and the baffle walls which divide it into numerous sections are kept continuously wet by the aid of these water sprays.

In the original design the baffle plates were made with an alloy of lead and antimony, while the interior walls and plates were lined with lead to protect them from the action of the dilute acid wash water. Later units, however, are lined with hard rubber in place of lead, since that material not only protects the metal, but withstands better the abrasive action of the coarser particles of ash and grit in the cyclone portion of the washer. The last three compartments of the chambers are provided with vertical walls which split up the gas stream and cause it to pass through very narrow concentric channels on its way to the chimney. These channels are provided with water sprays, as in the other sections of the apparatus, and it is in this portion of the washer that the very fine particles of ash, which are too light to be caught and removed by centrifugal forces, are brought into contact with the walls and are washed down by the water into the lower portion of the chamber. The mixture of water with grit and fine ash forms a slurry, which collects in the funnel-shaped bottom of the washer and passes thence into a large separating tank, in which 80 per cent of the solid matter is allowed to settle. The effluent from this tank, if it is to be employed again in the washing apparatus, requires filtration to prevent choking up the nozzles of the sprinklers. A washer of this type has been in use at Oppau for four years, and the results obtained in two separate tests lasting one hour are given in the original article.

The Modave System. This system is employed in a large

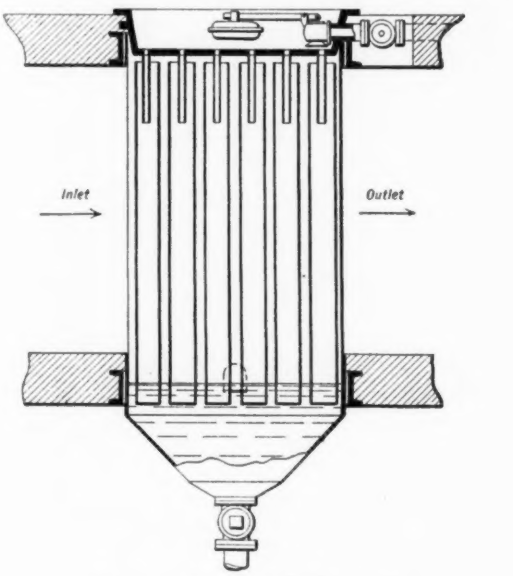


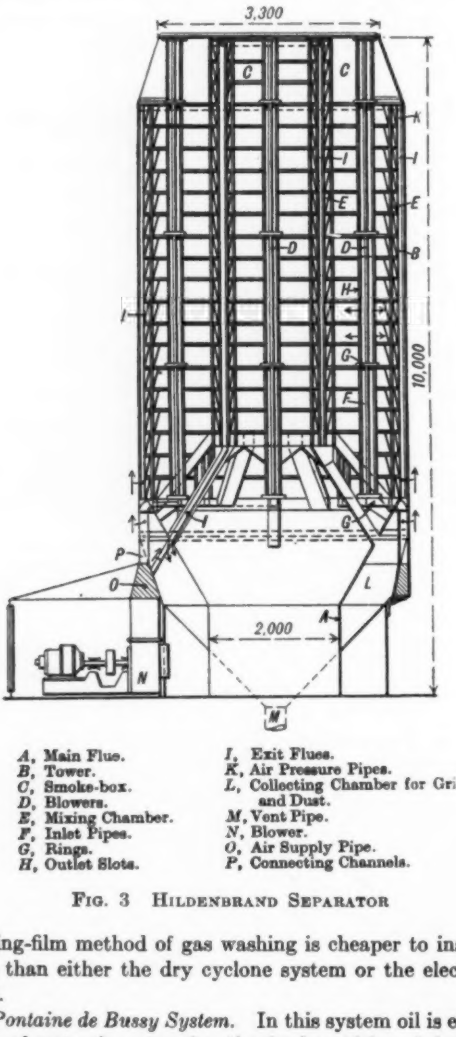
FIG. 2 MODAVE GAS WASHER

number of power plants in Belgium, France, and Italy, as well as at the Billingham plant in Durham, England. The washer, Fig. 2, consists of a series of rectangular tubes closed at one end and placed vertically and at right angles to the path of the escaping gases. The water, which is supplied from a tank placed above installation, flows first into the interior of each tube, and then rises within it until it flows over the top. In this way a thin film of water passes continually down the outside of each rectangular tube, and as the elements of the washer are staggered, the dust-laden gases, on their path to the chimney, are brought into close contact with the water film, which retains all the finer dust particles.

The washer is entirely automatic in action, and in order to maintain the required flow of water over the exterior of each element, it is only necessary to maintain a constant level in the supply tank, and to adjust the inlet and outlet valves of the washer according to the amount of dust in the escaping gases. The water consumption of the standard type of washer, with six rows of elements, is stated to be 3 to 4 gal. per 1000 cu. ft. of gas, and the temperature drop is approximately 125 deg. fahr. If the wash water can be recirculated, only one-third of the above quantity is required, but if it is acid, some arrangement must be made for neutralizing it. As regard efficiency, tests made at the electric power station at Auvelais, in Belgium, showed a dust

recovery between 92 and 97 per cent, and an absorption of sulphur acids equivalent to 70 per cent of the total amount present in the gas. Other figures for the efficiency of the Modave washer have geen given by Rammler for the installation of the power station at Issy-les-Molyneaux, near Paris. At this station 60 per cent of the ash contained in the fuel was found in the gases passing to the chimneys, and the Modave installation has enabled 90 per cent of this fine ash to be caught before the gases are discharged.

The author quotes a passage from a previous publication explaining why this type of washer was selected for the Bellingham steam plant, and what problems had to be overcome in the design of a film type of washer. Incidentally he states that under the conditions obtaining at Bellingham it has been proved that



A, Main Flue.
B, Tower.
C, Smoke-box.
D, Blowers.
E, Mixing Chamber.
F, Inlet Pipes.
G, Rings.
H, Outlet Slots.
I, Exit Flues.
K, Air Pressure Pipes.
L, Collecting Chamber for Grit and Dust.
M, Vent Pipe.
N, Blower.
O, Air Supply Pipe.
P, Connecting Channels.

FIG. 3 HILDENBRAND SEPARATOR

the falling-film method of gas washing is cheaper to install and operate than either the dry cyclone system or the electrostatic method.

The Pontaine de Bussy System. In this system oil is employed in place of water for removing the final particles of dust. It is also of the film type, and the advantage claimed for oil in place of water are that it can be employed with waste gases up to a temperature of 350 deg., and that the mixture of oil and dust can be separated easily on standing into two portions and can then be cleaned, but only with a considerable loss of oil. The use of bitumen or pitch has been suggested in place of oil.

The Juwil Washer consists of a combination of a dry type of grit and dust separator using the bag filtration principle, with a wet film or dust catcher for the finer particles.

The Hildenbrand Separator. This is one of the latest German designs for the treatment of waste gases from boiler plants burning dust or lignite fuel. The separator, Fig. 3, consists of a tower constructed on the columnar principle, in which the speed of the gases, as they pass from the main flue, is first reduced by one-half. This expansion is followed by a change in the direction of the flow from vertical to tangential by means of air blasts supplied by rod-shaped blowers on air circulating pipes, carried up through the interior of the tower. The fine dust and ash, which are separated partly by centrifugal action and partly by gravity, are carried into the V-shaped collecting channels, shown in Fig. 3 and pass thence down into the dust-collecting chamber *L* at the foot of the tower, and are then led for discharge to the bent pipe at *M*. No data have been published for the efficiency of this system of dust recovery from waste gases, but according to German engineering authorities the Hildenbrand tower is highly efficient for the dry separation of fine dust and grit, and can be easily combined with a wet washer for separation of sulphur acids.

Hardinge Rovac Plant. This has been installed on the newest extension of the boiler plant at the works of the Derby Corporation Electricity Committee and consists of a Hardinge thickener for the slurry combined with a Rovac filter provided with a filtering surface of 75 sq. ft. for recovering the fine dust and ash from the wash water. The flue gas before its discharge into the atmosphere is obliged to pass through one or more screens of water produced by sprays which give a very high degree of atomization. A whirling spray has been found very effective for producing a mist of water over the whole area of the flue or chimney. The mixture of water and fine ash or slurry which is obtained in this way falls by gravity into a sump at the base of the chimney. For a coal containing 15 per cent of ash, from 3 to 4 tons of wash water are required per ton of coal consumed, provided that the heavier portion of the unburnt coke and grit has been already removed from the waste gases by one of the dry centrifugal types of dust separator. (John B. C. Kershaw, F.I.C., in *The Engineer*, vol. 151, no. 3930, May 8, 1931, pp. 504–506, 7 figs., *d*)

THERMODYNAMICS

Heating by the Refrigeration Cycle

MANY years ago Lord Kelvin pointed out that the Carnot cycle, being made up of reversible processes, might also be used as a basis for the operation of a warming engine. Instead of utilizing the expansion changes to convert the heat energy of a hot body (steam) into work, thus giving up the remaining heat units to the cold body (the condenser) during the isothermal compression, isothermal expansion of the gas could be arranged to remove heat from a body at a comparatively low temperature and, by adding a small amount of energy needed during compression, the sum of these two energies could be given up to another body as heat at a relatively higher temperature than the first.

The author compares the Carnot cycle with a refrigeration cycle on the basis of a temperature-entropy diagram and shows that the quantity of heat produced by reversing the process, working between the absolute temperatures of, say, T_1 at the boiler and T_2 at the condenser, is very much greater than the heat equivalent of the energy put into compressor work. In other words, the expenditure of one kilowatt-hour of electrical energy in driving on an ammonia refrigerating compressor may very well mean the abstraction of an amount of heat equal to 4 kw-hr. from a cold-storage room and the liberation of an amount of heat equivalent to 5 kw-hr. in the cooling water.

His calculation shows that by the expenditure of 46 B.t.u. in the form of work in the compressor it is possible to remove 200 B.t.u. from the refrigerator and to transfer 246 B.t.u. to the cooling water with an approximate coefficient of performance of 500.

From a practical consideration for domestic use a small refrigerating plant in the basement of a house, consisting of an evaporator, compressor, and condenser, could be used. In the winter a fan could blow air over the condenser through the ordinary hot-air circulating system, and in the summer, by operating an ordinary butterfly valve, the air could be blown over the evaporator, thus heating the house in winter and cooling it in summer.

For example, with the standard commercial-size refrigerator for 900 watts input to the compressor, the evaporator provides 4960 B.t.u. per hr., and the condenser receives approximately the sum of the mechanical input and the heat absorbed by the evaporator, or $(0.9 \times 3412) + 4960$ B.t.u. per hr., making 8030.8 B.t.u. per hour, which is equivalent to 2.35 kw-hr. of heating effect obtained from an expenditure of 0.9 kw-hr.

This is just a practical application of an existing machine, but, as explained in the theoretical discussion, if the outside air is at

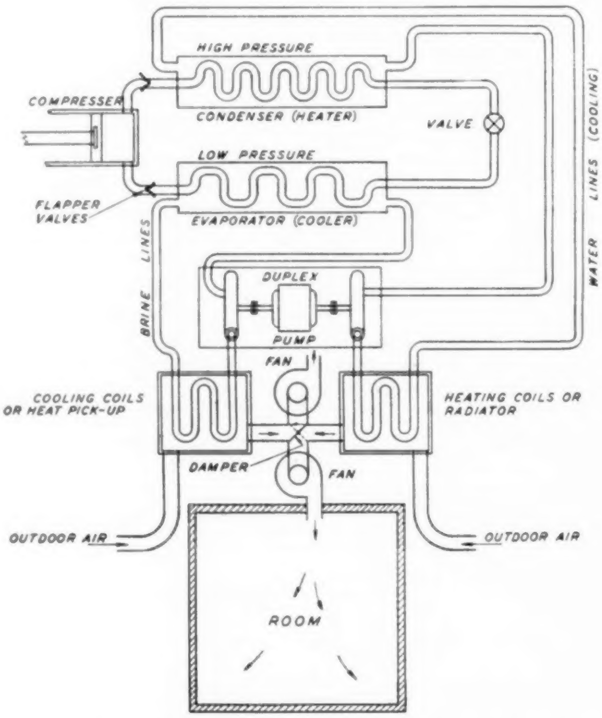


Fig. 4 Installation Diagram for a System of Heating by Means of a Refrigeration Machine

50 deg. and the incoming air is to be heated to, say, 80 deg. to give a room temperature of 70 deg., the effectiveness of a refrigerator used as a warming engine is increased many times.

A practical method of utilizing the heat thrown off by a refrigerating or air-conditioning installation is shown in Fig. 4. This development is the product of several years' research by the Mechanical Heating Company of Los Angeles, Calif. It will be noted that a standard refrigerating unit is adapted for this service by the addition of two water coils, one of which is the cold-water circulating coil and the other the circulating coil carrying the compressor cooling water. A feature is that the several circulating systems are completely enclosed, the refrigerating medium following the conventional cycle in the compressor and expansion chambers and the chilled water and cooling water being pumped around their respective systems by means of a dual pumping unit driven by a motor. For cooling the room, the external air is drawn over the cold-water coil and pumped into the room, while another fan draws external air over the cooling-water coils, and, after absorbing the heat from the cooling water, discharges it outdoors.

Up to the present time only a few experimental units have been installed for heating small residences or offices but this system of heating has been adopted in a large building now being completed in Los Angeles.

This system, which, it is claimed, can satisfactorily transfer approximately five heat units for the expenditure of one, making the total available for practical use, and at the same time provide by a mere throw of a valve a supply of air for cooling purposes, is novel from the engineering standpoint and is said to be practical for building heating, particularly in climates where air conditioning providing for both heating and cooling is desired. On the basis of securing power input to the compressor on a commercial rate of 1 cent per kw-hr., it is estimated that commercial heat made available by this system thus would cost the consumer approximately 2 mills per kw-hr. (W. R. Chawner, Southern Sierras Power Co., in *Electrical West*, vol. 66, no. 4, Apr. 1, 1931, pp. 177–179, 2 figs., *d*)

WELDING

Strength of Welded Shelf-Angle Connections

These tests were made to determine the strength of welded connections of the seat-angle type for use in steel frame buildings. In this type of connection, angles are welded to the outside of the flanges or to the inside of the flanges of rolled steel columns. The ends of the beams and girders which carry the floor are supported on these angles. The effect of changing the dimensions of the shelf angles and the location of the welds with respect to the angles were studied.

The values of the maximum loads and the corresponding values of the maximum loads per unit length of weld and maximum stresses are given in a table in the original article.

From this investigation it would appear that each specimen failed through the weld. Therefore the properties of the material in the column and in the angles had little or no effect upon the values of the maximum load.

For the specimens having welds only at the ends of the angles the average maximum stress in the welds increased as the width of the vertical leg of the angle was increased.

There were no definite indications that the width of the vertical leg of the angles affected the strength of the specimens.

Neither the thickness nor the length of the angles appeared to have much effect on the strength of the specimens.

Shelf-angle connections similar to those tested in this investigation, with reinforced fillet welds, will have a factor of safety of about 4 if they are designed with the following assumptions: (*a*) The forces act in the face of the column; (*b*) vertical fillet welds are stressed in shear; (*c*) horizontal fillet welds at the heel of the angle are stressed in tension; (*d*) horizontal fillet welds at the toe of the angle are stressed in compression; and (*e*) the allowable stresses are those given in the Code for Fusion Welding and Gas Cutting in Building Construction prepared by the American Welding Society. (James H. Edwards, H. L. Whittemore, and A. H. Stangin, in *Bureau of Standards Journal of Research*, vol. 5, Oct., 1930, pp. 781–792, 5 fig., *e*)

CLASSIFICATION OF ARTICLES

Articles appearing in the survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the society.

Engineering and Industrial Standardization

I.E.C. Publications on Steam Turbines

FOR the first time in the history of steam engineering a set of rules and regulations for acceptance tests of steam turbines has been developed and approved for use in international commerce by twenty-eight commercial nations.

This group of nations functioning through their national committees of the International Electrotechnical Commission under the guidance of Advisory Committee No. 5 on Steam Turbines have given their best talent in the preparation of this code or set of rules and regulations. The United States National Committee of the I.E.C. has functioned as the Secretariat for Advisory Committee No. 5 on Steam Turbines. The American Society of Mechanical Engineers through the activity of its Main Committee on Power Test Codes has contributed a considerable amount of the foundation material.

In its final printed form the I.E.C. Publication on Steam Turbines consists of:

Part I (No. 45)
- SPECIFICATION
- Appendix A—Information to be supplied with inquiry or order for steam turbines
- Appendix B—Suggested standard ratings
- Appendix C—Suggested standard steam pressures
- Appendix D—Graphical symbols for heat-power systems

Part II (No. 46)
- RULES FOR ACCEPTANCE TESTS:
  - Section 1—Object and scope
  - Section 2—Enumeration and description of terms, including letter symbols for heat and thermodynamics
  - Section 3—Guiding principles
  - Section 4—Mandatory rules for instruments and methods of measurement
  - Section 5—Computation of results
  - Section 6—Report of tests carried out in accordance with I.E.C. Rules for Acceptance Tests

Copies of these publications may be obtained from the Office of the Secretary of the United States National Committee, I.E.C., Room 1018, 33 West Thirty-Ninth Street, New York, N. Y., at the price of $0.50 per copy for publication 45, Specification, and $1 per copy for publication 46, Rules for Acceptance Tests.

New Code for Automatic Brakes and Brake Testing

OVER thirty national organizations, representing the manufacturers of automobiles, automobile associations, government bodies, and outstanding technical organizations, will cooperate in the preparation, under the auspices of the American Standards Association, of a new national safety code for automatic brakes and brake testing. The new code, replacing the present national code which covers only two-wheeled braking systems for passenger cars, will cover all types of braking systems now in use for both passenger and commercial vehicles.

The American Automobile Association and the U. S. Bureau of Standards have assumed the technical leadership of the work under American Standards Association procedure. The actual preparation of the code will be in the hands of a nationally representative technical committee which will base its recommendations on the results obtained from the fundamental research to be carried on by the committee. When the code is completed by the committee and approved by the American Automobile Association and the Bureau of Standards, it will be submitted to the American Standards Association for its approval as a national standard. Thirty-two organizations including national associations and state and federal bodies will be officially represented on this technical committee which is preparing the safety code for brakes and brake testing.

The personnel of a sectional committee which will revise the present American Tentative Standard Safety Code for Brakes and Brake Testing has been approved by the A.S.A.

Standardization of Foundry Equipment

THE organization of the sectional committee on standardization of foundry equipment (B45) has just been completed under the procedure of the American Standards Association. E. S. Carman, president of Edwin S. Carman, Inc., Cleveland, Ohio, is chairman of the committee, and John J. Baum, development engineer, Steel Founders Society of America, New York, N. Y., is secretary.

The work of the committee has been divided between three subcommittees which will cover the following subjects:

Subcommittee 1: Pattern plates; molding-machine parts affecting interchangeability of patterns; flask pins and holes; general dimensions of stock flasks for jobbing work

Subcommittee 2: Ladle and ladle shank sizes; ladle sleeves, stoppers, and nozzles

Subcommittee 3: Stock core print sizes, shapes, and finish allowances; pattern markings; rapping plates; fillet sizes; dowel pins for metal patterns and metal core boxes.

The project is under the joint sponsorship of the American Foundrymen's Association and The American Society of Mechanical Engineers.

The membership of the committee consists, at the present time, of representatives of twenty organizations, although it is expected that additions will be made from time to time.

Revised Safety Code for Elevators

MANY important developments in the manufacture and operation of elevators are reflected in the new revision of the American Standard Safety Code for Elevators, Dumbwaiters, and Escalators just published. For six years since the publication of the preceding edition of this code a research committee has been at work developing information and testing certain elevator equipment to provide data for the use of the Sectional Committee of which S. W. Jones is chairman.

During the process of revision every section and rule of the 1925 edition of the code was carefully reviewed in the light of recent progress and the necessary changes and additions made. Complete safety to the great numbers who are now compelled to travel in elevators has always been the guiding principle.

Since the statistics show that between 80 and 90 per cent of all elevator accidents occur at landings, the rules will therefore, require landings to be made as safe as the art permits by so equipping all cars and shafts that no car can be moved from a landing until both the car gate or door and the hoistway door is closed.

Copies of this code are now available at the office of the A.S.M.E. at $1 per copy.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Below are given records of the interpretations of the Committee in Cases Nos. 666, 677 (Reopened), 683, 686 to 691, as formulated at the meeting on June 27, 1931, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

CASE NO. 666

Inquiry: Do the provisions of Pars. P-195 and U-36 for increasing the thickness of heads when manhole or access openings are used, apply also to large nozzles when attached to dished heads? If it is necessary to so increase the thickness, what is the minimum diameter of nozzles to which these requirements do apply?

Reply: The provisions of Pars. P-195 and U-36 for increase of thickness of heads containing manhole or access openings do not apply in the case of openings for nozzle fittings which are attached to the head and reinforced in accordance with the requirements of Pars. P-268 and U-59.

CASE NO. 677 (Reopened)

Inquiry: May the longitudinal seams of tanks for the storage of air or water under pressure be made under the rules of the Code for Unfired Pressure Vessels by using the electrical resistance compression butt weld method? This process of welding involves bringing the two edges of the sheet together at one point and applying locally and continuously a current of sufficient intensity to bring the edges to the welding temperature and while the heated section is in a plastic condition, compressing the edges together so as to obtain thorough union thereof.

Reply: It is the opinion of the Committee that although this method of welding is not provided for in the Code, it may be used with safe results provided the material and construction of the tank come within the requirements of the Code, and provided:

That the plate used for tanks described and for this method of welding shall meet the requirements of Specifications S-2 for Steel Plates of Flange Quality for Forge Welding;

That this method of welding be limited to the use of plate not over 0.15 in. in thickness;

That prior to the welding operation, the edges of the plate and the electrical contact area shall be clean so as to free those surfaces from scale, oxides or grease;

That the weld be made progressively and continuously over its entire length;

That the offset of the edges due to the compressing shall not exceed 60 per cent of the thickness of the plate;

That the prescribed tests for the hydrostatic pressure as specified in the Code are complied with;

That the unit stress shall not exceed 8,000 lb. per sq. in.

A revision of the Code to permit the above construction is under consideration.

CASE NO. 683

Inquiry: In the fabrication of A.S.M.E. Code power boilers and unfired pressure vessels, is it permissible to use seamless steel cylinders rolled to size from hollow ingots, in which the rolled cylinders are made in accordance with the specifications submitted (on file in Secretary's office), and in particular having the following minimum physical properties:

	Grade 1	Grade 2
Tensile strength, lb. per sq. in.......	60,000	75,000
Yield point, lb. per sq. in...........	0.5 tens. str.	0.5 tens. str.
Elongation in 2 in., per cent........	26	24
Reduction of area, per cent.........	42	38

It is understood of course that these cylindrical shells will be assembled into vessels in accordance with the Code rules, by riveting, fusion welding, or other suitable means. It is noted that there is no existing specification in the Code for such material.

Reply: Pending the result of joint action of the Boiler Code Committee and the American Society for Testing Materials upon a Proposed Specification for Seamless Rolled Steel Cylinders, it is the opinion of the Committee that shells of pressure vessels and power boilers may be constructed of this material under the provisions of Sections I and VIII of the Code, provided the material conforms to the requirements of the Proposed Tentative Specifications.

CASE NO. 686

Inquiry: *a* Is it the intent of the Code to permit the omission of stress relieving of fusion-welded nozzles, when such are constructed in accordance with Fig. U-6, types A, C, D, and E and when the inside diameter in any case does not exceed that given in Fig. U-6 or by d in the formula in Par. U-77 where this formula applies?

b In the case of nozzles attached by fusion welding in tanks with seams of riveted construction and when the nozzles do not require stress relieving, is it the intent of the Code, as stated in the last part of Par. U-77, to allow the attachment of nozzles prior to the making up or attachment of the courses by riveting as an alternate to locating nozzles at a distance from the riveted seam equal to the diameter of the nozzle plus 4 times the shell plate thickness?

c When the inside diameter of an unreinforced fusion-welded nozzle given by d in the formula in Par. U-77 is greater than the largest diameter of an unreinforced circular opening, calculated by formula 1 or 2 in Par. U-59, may the latter value be disregarded in favor of the former, or shall that formula which gives the smaller value of d govern the size of the opening?

Reply: *a* Yes—attention is called, however, to the fact that under the proposed new rules for fusion welding, nozzles must be stress relieved on all Class 1 vessels and in some cases on Class 2 vessels.

b Yes—nozzles may be attached prior to riveting, whether stress relieving is required or not, but in no case after making

up or joining the courses by riveting shall stress relieving of any nozzles be permitted, nor after such riveting shall any nozzles be attached within the minimum distance specified in Par. U-77.

c The formulas and rules in Pars. U-59*a*, U-59*b*, and U-59*c* are for plain unreinforced openings, such as tube holes and other drilled openings, and connections where the welding is applied for sealing and not for strength. The size of an unreinforced fusion-welded nozzle is governed solely by the formulas and rules in Par. U-77.

CASE No. 687

Inquiry: Specification S-3 for Steel Plate for Brazing provides that sheets less than $^1/_4$ in. in thickness need not be stamped at the mill, but that the manufacturer must mark each vessel in some permanent manner so that the material can be identified. None of the other material specifications have provisions of this sort. May not this same provision be interpreted as being applicable to all sheets under $^1/_4$ in. in thickness when made to any of the specifications in the Code?

Reply: It is the opinion of the Committee that sheets less than $^1/_4$ in. in thickness should not be marked with a steel stamp and until such time as revisions can be made in those sections of the Code which permit the use of plates under $^1/_4$ in. in thickness, the provisions of Par. 6 of Specification S-3 should apply.

CASE No. 688

(In the hands of the Committee)

CASE No. 689

(In the hands of the Committee)

CASE No. 690

Inquiry: In the use of a forged flange inserted from the inside of the shell and seal welded as shown in Fig. U-3A, may the material in the flange be considered as a reinforcement?

Reply: No—the welding shown in Fig. U-3A is simply seal welding and not welding for strength. It is the opinion of the Committee, however, that the material in the flange may be considered as reinforcement only if the amount of welding is sufficient to transmit to the shell the stresses capable of being developed by the flange, and provided the welding is in accordance with that required in Fig. U-6.

CASE No. 691

Inquiry: May the thickness for a dished head with a reversed flange as shown in Fig. 27 be figured on the basis of a head

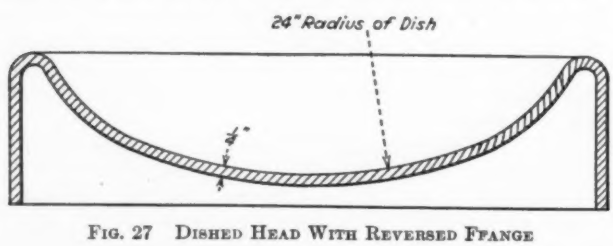


FIG. 27 DISHED HEAD WITH REVERSED FFANGE

concave to pressure? This is for use in a small tank constructed for 100 lb. working pressure.

Reply: It is the opinion of the Committee that a head of this design does not meet the present requirements of the Code. If it is desired to use such construction, specific data should be ubmitted to the Boiler Code Committee demonstrating the afety of the construction proposed.

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed at all times are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on its activities or policies in Research and Standardization.

Cause and Prevention of Heat Cracks in Aircraft Welding

TO THE EDITOR:

In his paper[1] Mr. George has given in detail a number of causes and suggestions for preventing so-called heat cracks in aircraft welding. The prevention of such cracks is the most important, and often the most difficult, problem in welded design.

Although the paper deals only with oxyacetylene welds on chrome-molybdenum steel, similar troubles are sometimes encountered when welding on different grades of steel and when welding by the electric-arc process. In general, however, the methods for preventing heat cracks as outlined by Mr. George are applicable to welds made on different grades of steel by either the gas or arc process.

The following statement as given in the paper should be given particular note: "While the full responsibility of avoiding heat cracks should rest on the welding operator, nevertheless the designer can often assist in the ease and economy of the welding, though he need not be restricted in design." If the maximum advantage is to be taken of the economical and mechanical properties of welding, the designer must be thoroughly familiar with the problems encountered by the welding operator. Many welding applications have proved unsatisfactory because of poor design which made it impossible for the operator to make satisfactory welds. If the designer is familiar with the operator's problems, this condition will not occur, and welding will be more efficiently used.

It might also be mentioned that in general practice butt welds present a greater problem from the standpoint of shrinkage strains and cracks than fillet welds. The writer has investigated the case of butt welds made on low-carbon steel by the electric-arc process. The results of this work[2] indicate that shrinkage stresses can be greatly reduced by using special welding procedures and by the application of peening. The same results can also be applied to fillet welds.

CHARLES H. JENNINGS.[3]

TO THE EDITOR:

Mr. George's discussion of "The Cause and Prevention of Heat Cracks in Aircraft Welding" represents thoughtful common sense applied to an important problem. It is to be hoped that it will be read by as many head welders and shop foremen as by designers and engineers, for it is in the shop that the application of such information is taken most seriously.

---

[1] "The Cause and Prevention of Heat Cracks in Aircraft Welding," by H. S. George. Published in MECHANICAL ENGINEERING, June, 1931, p. 433.

[2] "The Effect of Welding Procedure on Shrinkage Strains in Butt-Welded Joints," by C. H. Jennings, *Journal of American Welding Society*, April, 1931.

[3] Research Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Jun. A.S.M.E.

There is, however, another solution to the "heat crack" problem which can very often be applied and which effectively prevents heat cracks and saves welders hours as well. This might be called "partial welding." Partial welding means welding only as much of the parts as is necessary to secure adequate strength. It implies that the welding be so placed that a minimum of time will be required to do the work, and so as to be most effective mechanically. Partial welding can be applied in most of the fitting types in which heat-cracking difficulties occur. In these fittings it will often be found that there is much more welding than necessary. Often this is put in simply because "It looks better that way," or because "I didn't calculate the load, but it will be plenty strong the way it is."

The most obvious applications are in wire or strut lugs such as those illustrated in Figs. 3, 5, and 13 of Mr. George's paper. In case of the round steel welding washers so often added to wire lugs to increase the shear and bearing values, it is seldom necessary to weld more than half-way around.

If, for example, we assume an S.A.E. 1025 steel washer 0.063 in. thick, 1 in. O. D. and $^3/_8$ I.D., the largest load which it can transmit from the pin or bolt is in bearing and amounts to $^3/_8 \times 0.063 \times 90{,}000 = 2125$ lb. Using the very conservative figure of 2000 lb. per inch as the strength of the weld, the required weld is $100 \times 2125/2000 \times 3.14$ or about 35 per cent of the circumference of the washer. Likewise in many other fittings more than half of the welding can be advantageously omitted.

Some care must be taken in design to see that welding is left out at the points where cracks occur, such as at the intersection of an edge weld and a lap weld, or at points of sudden change in section. The total welding done should be divided into as few separated beads as possible. Tack welds or welds less than $^1/_4$ in. long should not be used. The principles are simple and are:

1 Distribute the welds symmetrically about the line of force so as to induce no moments or tearing tendencies.

2 Do not weld where cracks would occur.

3 Avoid annealing more of the base metal than necessary.

The two limitations of this method are that it allows internal corrosion if water is allowed to stand on the part, and that a slightly different welding technique is required.

External fittings, or fittings from which the protective coatings and finish might be removed in service, should be completely welded, as this is the best moisture seal. Most fittings in an airplane do not fall in these classes, and adapt themselves well to partial welding.

Little additional welding technique is needed. When one weld bead is completed, the welder, instead of jumping directly to the next, should keep the space between the welds hot enough so that the cooling of the first weld is retarded. With a few minutes' practice or instruction a welder can do this quite rapidly.

The method of "partial welding" is not new. It is being successfully used by many manufacturers, and can profitably be used by others. When carefully applied it is perfectly safe and satisfactory. It has the twofold advantage of eliminating cracks and eliminating wasted labor costs.

KENDALL PERKINS.[4]

TO THE EDITOR:

Mr. George's paper throws a considerable amount of light on the subject of heat cracks in aircraft joints, and by dispelling the darkness which has previously shrouded this question it has gone a long way toward eliminating that bugaboo of fitting designers, the edge weld. Joints between tubes and flat sheet where the weld was made close to or at the edge of the sheet have long been a source of worry to designers, due to the disproportionate amount of cracked welds discovered by inspectors in the factory or brought to light by failures in service. Many of the service failures in welded steel engine mounts which have been ascribed to fatigue are doubtless due to the alternating stresses developed by the vibration of the engine's being imposed on a welded joint, a portion of which is already heavily stressed due to uneven cooling of the weld metal or the base metal itself. If this local cooling has been sufficiently rapid to cause the formation of an edge crack, it should be perfectly obvious to any designer of welded structures that difficulties are to be expected when dynamic stresses are superposed on the already cracked and locally highly stressed joint.

Apparently many of our more troublesome "fatigue" failures are really due to a poor detailing of connections which calls for a mass of metal near the periphery of a sheet to which a member is to be attached by welding. As pointed out by Mr. George, such a mass of metal will conduct heat away from the interior portions of the weld and cool them more rapidly than the portion near the edge that is exposed to the slower cooling of the air. Yet how many designers give this point much, if any, consideration when laying our their joint details? In most cases with which the writer has had experience, no consideration has been given this point in the past, but welding has been looked upon as the one perfect means of making connections between steel parts; and, if later events showed imperfections, the technique of the welder was questioned—that of the engineer was not assailed.

Mr. George merits the thanks of the aeronautical engineering profession for pointing out that the design of the joint may be so faulty that the best of welders cannot produce satisfactory results except, perhaps, by the expenditure of a disproportionate amount of time and trouble. His description of the contraction causing cracks and the methods for preventing them are so clear and definite that many of the faulty details should, in the future, be avoided in the drafting room, leaving but few to be handled by the shop. The general strength and integrity of the more troublesome of the joints made by the standard methods of acetylene welding should therefore be improved.

A somewhat more difficult problem is introduced with spot welds as used with thin-gage sheets of stainless steel. Such welds frequently show cracks through the weld itself, for which the only apparent explanation is the non-uniform cooling of the welded spot. These cracks appear to be caused by the rapid cooling and contraction of the material a short distance from the center of the weld, the center being apparently the portion subjected to the greatest heat. This contraction is frequently sufficient to pull the material at the center apart and produce a crack through the weld. Such cracked spot welds as have been noted and tested show no material reduction in strength and no pronounced tendency to corrode as might be expected. Few data are yet available as to what effect such cracks may produce on spot-welded joints subjected to fatigue. Those available, however, indicate the effect to be negligible in so far as the strength of airplane wing ribs is concerned. Further information on this type of heat crack is desirable in view of the modern inclination toward the use of stainless alloys in aircraft production, and while it is in a somewhat different field from the studies conducted by Mr. George, the writer wonders whether or not Mr. George could throw any light on the problem of cracks in spot welds and how to prevent them. While not universal, they appear with sufficient frequency in metallurgical studies of such welds to be disturbing to airplane designers who are acquainted with them.

JOSEPH S. NEWELL.[5]

[4] Project Engineer, Curtiss-Wright Airplane Co., Robertson, Mo.

[5] Associate Professor of Aeronautical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers, and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

Roy V. Wright, *President*

Erik Oberg, *Treasurer* Calvin W. Rice, *Secretary*

COMMITTEE ON PUBLICATIONS:

F. V. Larkin, *Chairman* L. C. Morrow

W. H. Winterrowd S. F. Voorhees

S. W. Dudley

C. E. Davies, *Secretary to Publications Committee*

PUBLICATION STAFF:

G. A. Stetson, *Editor*

Frederick Lask, *Advertising Manager*

Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

By-Law: The Society shall not be responsible for statements or opinions advanced in papers or . . . . printed in its publications (B2, Par. 3).

Enrolment in Engineering Courses

A SUMMARY of enrolments in 145 engineering schools in the United States covering the academic year 1930-31 shows a total of 78,685 students, of which 73,386 were undergraduates. Of graduates, 2939 were enrolled. By curricula and courses, electrical, mechanical, civil, and chemical engineering students, in the order named, constitute by far the greatest number—more than 75 per cent of the total. The figures are as follows: electrical, 19,992; mechanical, 15,684; civil, 14,534; and chemical, 9667. Aeronautical engineering is seventh in the list with a total enrolment of 2057, mining and metallurgy and architectural engineering, listing 2944 and 2940, respectively. Forty-one courses and curricula are listed. Flour-mill engineering, with a total of 9 students, had the lowest enrolment.

Progress in Smoke Abatement

OPPORTUNITY to call attention to developments in smoke abatement has been afforded by notices of activities in two localities, Pittsburgh, Pa., and Hudson County, New Jersey, both congested industrial communities.

The work in Hudson County has been recently organized. It is being carried on in a district in which there are 1795 industrial plants, oil refineries, railroad locomotives, and steamships. Hudson County lies adjacent to New York City and thus contributes, under certain weather conditions, to the hazy atmosphere that frequently envelopes that city.

The work in Pittsburgh is reported in an article, "The Facts About Pittsburgh's Soot and Dust," by H. B. Meller, in the June-July issue of the *Pittsburgh Record.* Most of Mr. Meller's report deals with local conditions, but some important aspects of the smoke-abatement problem are also emphasized.

Mr. Meller concludes that it is possible to reduce, very materially, the dense smoke prohibited by law. However, visible smoke is only a small percentage of the total objectionable material emitted from stacks. At present no restriction is placed upon fuel dust and ash that come from stacks, and these, in weight, far exceed visible smoke. Nor is any control exercised over the emission of deleterious gases. Mr. Meller points out that the subject of sulphur oxides that result from combustion needs study, and that at present there is no satisfactory process for the economic removal of such gases from the waste gases of furnaces.

Engineers, generally, recognize the three elements of the problem as emphasized by Mr. Meller; visible smoke, dust and ash particles, and objectionable gases. Visible smoke, easiest to control, easiest to see, easiest to trace to its source, is first attacked by smoke commissioners. Success in its abatement has been achieved in localities where an intelligent study has been made and the cooperation of offenders has been tactfully enlisted. When dense black smoke due to improper firing or incorrect design is eliminated, visual evidence of improvement provides justification for the smoke commissioner's activities. But it must not be forgotten that eternal vigilance is the price of lasting relief, and that only one of the three factors of the air-pollution problem is being tackled in eliminating visible smoke. The elimination of dust and corrosive acids is more difficult and more expensive.

Using the Engineering Societies Library

A SURVEY of the engineering collections of 25 public and college libraries in New England, made by Julian A. Sohon, chief bibliographer of the Engineering Societies Library, New York, disclosed the fact that their technical facilities were good, but that a scarcity of qualified persons in charge led to a tendency to purchase engineering books blindly or only on request, and to the presence on the shelves of out-of-date books. Practically all libraries showed a decided lack of foreign technical books and periodicals, and none had a regularly organized search department. To improve conditions, Mr. Sohon suggests the formation of committees of engineers in each city to advise the city librarian in the selection and weeding out of books and periodicals. This suggestion is a practical one that can be adopted with profit. In the meantime, the report serves to emphasize the importance of the Engineering Societies Library in New York.

Statistics covering the activities of the Library, whose main collection is now in excess of 141,000 books and pamphlets, have recently been made public by the director, Harrison W. Craver.

During the first five months of 1931, 12,225 visitors were registered. Service was given to 17,726 members of the engineering profession, 2553 being served by telephone. In this period, 42 searches were made and 89 technical articles were translated. Orders for 21,691 photoprints were received from 2136 persons. Information was sent to 1561 members by letter and books were loaned to 90 distant members at their request.

These statistics indicate the extent to which the library is used and should be suggestive to those who may not have availed themselves of the services that it is organized to render.

Engineers who make use of the Engineering Societies Library by mail will expedite replies to their requests by being more specific in their inquiries. Such requests as a "list of everything on the subject," or "a complete bibliography" are generally made without a knowledge of the time and expense involved in complete searches. Few persons really want a "complete bibliography." A request for a brief list of good articles on a subject will generally bring greater satisfaction at less expense and in a shorter time. Time is also saved by writing directly to the library and not to the

secretary of the society to which the engineer may belong. It is more helpful to state the date on which the information is required than to use the indefinite expression "as soon as possible."

Engineers' Earnings

ELSEWHERE in this issue will be found a report of the A.S.M.E. Committee on the Economic Status of the Engineer. Compiled from the results of a questionnaire returned by more than half of the members of this society in the United States, the statistics may be considered as representative an indication of the earnings of mechanical engineers in 1930 as could be got together on such a basis. They reveal some interesting facts and cannot help but be of intense interest to all engineers. They provide the means by which each individual engineer may compare his economic position with that of others, a process that is bound to bring a measure of satisfaction to some and present a frank challenge to all. A program of A.S.M.E. activity to make use of the results of the questionnaire is yet to be formulated.

There are those who will complain that earnings do not constitute a basis for measuring professional success, and who will criticize an inquiry on the part of a professional society into this aspect of its members' affairs as being a function better befitting a trade union. Such critics fail to evaluate properly other implications of the study than that which makes it a basis for a class bargaining to increase the incomes of engineers.

Concern for one's economic condition and a desire to increase one's income are neither unnatural nor unprofessional. The question of earnings is a paramount one with any individual or group of individuals. None but an unpractical idealist, or a person of independent means, will disregard the importance of providing for himself and his family in such a social and economic order as exists in this country today. Within reasonable limits there is an obligation laid upon responsible citizens to secure as abundant a return as is possible from whatever capital they may possess of ability, training, and opportunity. This is based upon no sordid view of life but upon the very real exigencies of a very real situation. And after all, rightly or wrongly, there is no indication of economic status more accurate for an appraisal than earned incomes considered on comparable bases.

In a summary of the report the Committee has ventured some generalized conclusions based on the statistical evidence at their disposal. Few will, we believe, disagree violently with these findings. Many will, it is hoped, ponder their significance. In them are to be found grounds for certain satisfactions and a bolstering up of opinions that have been commonly expressed. Most of them are easily explained, although certain details touched on in the report will cause surprise. But most significant of all of these summarized outstanding points is the final one, "that the differences in earning power between men whose work is exclusively technical and those who combine with their technical ability the capacity to handle independent businesses or to manage men or affairs, are great—so great as to indicate the importance of most engineers' seeking to develop themselves in this respect, and of engineering schools' bending their curricula somewhat toward this end."

It is to this revealing fact that attention should be most urgently directed. Practitioners, teachers, and those about to enter the profession of mechanical engineering should ponder it well, for its implications are wide. It reflects a fundamental law of life that is as old as life; and as a Greek dramatist wrote 2500 years ago, "all is vain.... that striveth beyond the laws that live."

How to acquire this powerful quality that is so important to success wherever human beings are concerned we do not know. If a man is not born with it in his character he quite possibly may never acquire it. If he does not cultivate it he squanders a precious heritage. If he does not realize its absence he is likely to be doomed to a thwarted and disappointed career should he attempt one in fields where such a gift is necessary. All in all it is a fundamental to be thoughtfully considered, lest a lame man become soured and find life fruitless and unhappy because he cannot run a race.

These are thoroughly practical considerations that are treated in the report. They do not represent conditions as they might be but as they are. The wise man will take heed of them in his own plans and will bear them in mind when he counsels others.

The Part of the Engineer

IT IS not generally realized how profound has always been the part of the engineer in shaping human history. The introduction of the steam engine and the railroad, for example, are known to have been important factors in the Industrial Revolution. What is less realized, however, are the great and rapid changes created by the engineer or as a result of his achievements in modern society and still going on before our eyes. It has been stated that radio broadcasting, besides becoming a great force generally, has already changed the American taste in music. When radio programs were first broadcast, jazz prevailed because the public liked it, and the public liked it because it had had few opportunities to hear anything better. When radio brought to the American home the works of masters of music rendered by masters of its reproduction, the sway of the jazz, according to those who are supposed to know about it, began to give way to that of other forms of music.

The radical influence of the automobile on the whole structure of American life is so great that even we who are of the generation that witnessed the appearance and development of the automobile scarcely realize its scope. In a short period of years, the automobile has already exerted a deep, and to many a disturbing, influence on morals. It has proved of vast benefit to farmers formerly isolated throughout most of the year. It has brought together the countryside and the city in a manner that could have scarcely been believed fifteen or twenty years ago and incidentally has changed not only the attitude of the farmer toward the city but his manner of speech and dress, and his outlook on the world.

In the not-distant future other developments are certain to come about. There will be television, for example, which even more will make of the world one single family, possibly not without those quarrels which occur in any but the best or dullest of families. Aviation is certain to become a universal force for good or evil depending on the effect of moving from place to place at 200, 300, or perhaps 500 m.p.h. In any event it will annihilate distance between places even more effectively than did the introduction of railroads and automobiles and likewise undoubtedly will give a broader outlook to the people.

In a recent speech President Hoover outlined a plan for America. In the next twenty years there will be in this country a 20,000,000 increase in population. For this will be built 4,000,000 new and better homes, thousands of new and still more beautiful city buildings, and thousands of factories. The capacity of the railroads will be increased, thousands of miles of highways and waterways will be added. Twenty per cent more farm products will be grown and 25,000,000 additional electrical horsepower will be installed. This is a program which any engineer can visualize and endorse; and it is not without significance that President Hoover adds, "We plan more leisure for men and women and better opportunities for its enjoyment, a greater diffusion of wealth, and a decrease in poverty."

The Small Plant

At the Detroit Meeting of the A.S.M.E. last year Col. Crosby Field presented a paper before a joint session of the Management Division of the Society and the American Management Association on the subject of the small industrial plant. His paper was presented in the October, 1930, issue of Mechanical Engineering and received much favorable attention. At that time mergers and consolidations were very much in the public mind and "big business" with its greatly advertised advantages and efficiencies was receiving an unusual amount of attention. Small plants existed then, as now, in great numbers, but interest was with the large ones, and the problems discussed before engineering and other professional societies were largely viewed in the light of conditions existing in plants employing more than 500 persons.

Last month, fourteen months after the Detroit Meeting, a conference on Management Problems of the Smaller Industries, sponsored by the Silver Bay Association, was held at Silver Bay on Lake George, N. Y. In view of the 193,562 plants that employ 500 persons or less, an attendance at the conference of only 80 was disappointing and obviously unrepresentative, but interest and enthusiasm and an excellent program overshadowed in significance the small attendance. Made thoughtful and serious-minded by the sobering experiences of hard times, the men who attended this conference, as well as those who addressed them, indicated no easy paths back to the broad road of prosperity. Hard work, common sense, and enlightened self-interest offered the most promising possibilities to these men whose responsibilities, in many cases, covered all or a majority of the principal executive duties of the companies they represented. No subject touching the conduct of a manufacturing business was foreign to their interest. This resulted in lengthy and animated discussion.

Getting together a group of managers of smaller plants as was done at the Silver Bay conference serves to emphasize the fundamental soundness of proper management methods, to stimulate faith, and to reaffirm policies. This years' conference is to be repeated next year as a further experiment. When the announcement of the date and program is made, engineers interested in the problems of the small plant will do well to make arrangements to attend. American business needs all of the clear thinking possible, and nothing serves better to crystallize a worthwhile idea, or to discourage a foolish one, than free and intelligent discussion. The coming years are likely to see increased attempts at social legislation, most of which will probably be distasteful to industrialists. Enlightened self-interest would seem to dictate intelligent progressive action by industrialists on problems of public welfare in anticipation of schemes to solve social and economic problems by means of legislation. Small plants will always be an important factor in our industrial life. Conferences for the benefit of their managers are to be encouraged.

The Hoover Medal

The Hoover Medal

A recently published booklet[1] commemorates the award of the Hoover Medal to the President of the United States. The presentation of this award, it will be remembered, took place at the Fiftieth Anniversary Dinner of the A.S.M.E. on April 8, 1930, at the Mayflower Hotel in Washington, D. C.

The trust fund creating the award was the gift of Conrad N. Lauer, of Philadelphia. It is held by the A.S.M.E. and is administered by a board consisting of representatives of the A.S.M.E., the A.S.C.E., the A.I.M.E., and the A.I.E.E.

The medal was instituted to commemorate the civic and humanitarian achievements of Herbert Hoover. From time to time it will be awarded by engineers to a fellow engineer for distinguished public service.

The reverse side of the Hoover medal depicts a workman operating a metallurgical furnace and surrounded by the tools of his trade. This scene was taken from an illustration in Agricola's "De Re Metallica," a treatise on the state of metallurgy in medieval times, translated by Herbert Hoover and Lou Henry Hoover.

President Hoover's achievements in humanitarian as well as engineering services are set forth in one section of the booklet. To the unusually brilliant record which furnished the basis of the award for "distinguished public service," the medalist has since made notable additions. Within the past few months his leadership in world affairs has been most convincingly demonstrated by the suggestion of a moratorium of international debts that has had a powerful and stabilizing effect on international relations and on national finances, particularly in Germany. The first recipient of the Hoover Medal is setting a standard of achievement that future medalists will find difficulty in attaining.

[1] "Herbert Hoover, Medalist." Published by the Hoover Medal Board of Award, New York, N. Y., 1931.

Book Reviews and Library Notes

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E., and the A.I.E.E. It is administered by the United Engineering Trustees, Inc., as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Connecticut Clockmakers

Connecticut Clockmakers of the Eighteenth Century. By Penrose R. Hoopes. Hartford, Conn.: Edwin Valentine Mitchell, New York: Dodd, Mead & Company, 1930. Cloth, 7³/₈ × 10 in., 178 pp. with plates and indexes, $10.

Reviewed by Joseph W. Roe[1]

A GOOD book, beautifully illustrated and printed, of interest to engineers as well as antiquarians. The very name "Connecticut clock" suggests a raucus little alarm clock far removed from the stately, leisurely heirloom on the hall landing, but the work of the eighteenth-century Connecticut clockmakers equaled the best in other colonies and in England.

"They were the pioneer machinists, and the tiny shops in which they worked were the earliest machine shops, furnished with metal-turning lathes, gear-cutting machines, wire-drawing and screw-cutting equipment, foundry, and forge-shop tools. Their work was of the most scientific, accurate, and complex nature, their product was the most intricate known to the age in which they lived, and their influence upon the spread of sound technical skill was of incalculable value to the colonies."

The first American clockmakers settled in Boston in the 1680s. The trade was well established in New York and Philadelphia by 1700. Connecticut had no towns approaching these in size, and was so distinctly rural it is surprising that the trade should have taken root at all. That it did so is a clear indication of the aptitude of its people for high-grade manufacture. Many of the early clockmakers worked in the small towns and villages and peddled their output themselves, going as far afield as Pennsylvania and even the southern colonies for a market.

The majority of the eighteenth-century clocks were tall case clocks, weight driven, with pendulums. They were sold directly by the maker, and usually without the cases, the purchaser having the case made by some local cabinet maker. When both movement and case were made by the clockmaker they were treated as separate items. The item "clock" covered the movement proper, dial, hands, pendulum, and weights, only.

The first Connecticut clockmaker was Ebenezer Parmele who began business in Guilford in 1712. Maycock Ward, an apprentice of his, settled in Wallingford in 1724 and worked there for nearly sixty years. A nephew, Abel Parmele, and probably Seth Youngs were also his apprentices. Most of the Connecticut clockmakers seem to have learned their trade within the state. A few were trained in Massachusetts but the exchange between the colonies seems to have been fairly equal. One Englishman, Thomas Harland, landed in Boston in 1773 on one of the ships which precipitated the Boston Tea Party. He settled in Norwich and had a wide influence for the quality of his workmanship and for the men he trained. Daniel Burnap, first of East Windsor, later of Coventry, was another craftsman of great skill. His brass eight-day clocks are among the most beautiful of Colonial timepieces. One of his first apprentices was Eli Terry who became the foremost clockmaker of America.

Terry established himself first at East Windsor, and a few years later at Plymouth in the upper Naugatuck valley. Here he began making wooden clocks in quantity, using water power. In 1808 he was at work on a single order for 4000 clocks. In 1815 he designed a 30-hour shelf clock of which hundreds of thousands were produced. Chauncey Jerome, who worked for him, applied Terry's methods to brass clocks, and between them they introduced interchangeable manufacture into the industry and doomed the old individual clockmaker. In his later years Terry, satisfied with success as a manufacturer, turned back to producing a few high-grade special clocks largely for his own pleasure until his death in 1852. He was, therefore, not only the first of clock manufacturers but almost the last of the craftsmen.

Mr. Hoopes gives in the first part of the book a general account of the pioneer days of the craft, of the early types of brass and wood clocks and of public clocks, and of the tools and methods used in making them. In the second part he gives short biographies of 79 clockmakers who were working in Conneticut prior to 1800. In about 15 of these biographies he gives the lists of tools inventoried in their estates, which are of interest as showing with what meager equipment these men produced such good work. In few cases does the value amount to more than one or two hundred dollars.

The book contains 40 pages of plates of dial and tall clocks, a bibliography, and indexes. It is an interesting piece of industrial history, well done both as to authorship and book work.

[1] Professor of Industrial Engineering, New York University, New York, N. Y. Mem. A.S.M.E.

Books Received in the Library

Air Brake Inspector's Handbook. By C. O. Glenn. Second edition. Simmons-Boardman Publishing Co., New York, 1931. Leather, 5 × 7 in., 328 pp., illus., diagrams, charts, tables, $3.50.

Describes in detail the types of brake equipment in current use on American railroads and gives directions for inspection and testing.

Applied Kinematics. By J. H. Billings. D. Van Nostrand Co., New York, 1931. Cloth, 6 × 9 in., 173 pp., illus., diagrams, charts, table, $2.50.

Extensive use is made of graphical methods in this text, and the machines used to illustrate principles are up-to-date in type. Special prominence has been given to the question of acceleration. Many problems are given.

Business Administration. By W. Wissler. McGraw-Hill Book Co., New York, 1931. Cloth, 6 × 9 in., 897 pp., diagrams, charts, tables, maps, $5.

An interesting, readable presentation of the various factors that affect the problems which confront the administrator of business enterprises. Money, markets, men, machines, materials, and methods are examined, and their relations to each other are discussed. A critical inquiry into the nature and ends of business as a complex institution aims to show executives where business stands today and the line along which it is developing.

Darstellende Geometrie. Third part. (Sammlung Göschen Bd. 144.) By R. Haussner and W. Haack. W. de Gruyter & Co., Berlin and Leipzig, 1931. Cloth, 4 × 6 in., 141 pp., diagrams, 1.80 r.m.

The final volume of this concise text-book treats of problems involving the cylinder, cone, sphere, screw, etc.

Dyke's Automobile and Gasoline Engine Encyclopedia. Sixteenth edition. By A. L. Dyke. Goodheart-Willcox Co., Chicago, 1931. Leather, 7 × 10 in., 1233 pp., illus., diagrams, charts, tables, $7.50.

The fundamental principles of automobile construction, operation, and maintenance are set forth in simple language and minute detail and illustrated by a wealth of diagrams. The book apparently includes everything that an owner or repair man can possibly need to know.

Elements of Chemical Engineering. By Walter L. Badger and Warren L. McCabe. McGraw-Hill Book Co., New York, 1931. Chemical Engineering Series. Cloth, 6 × 9 in., 625 pp., illus., diagrams, chart, tables, $5.

An admirable textbook, covering the unit operations of chemical engineering both in theory and in practical application. The theory is developed as simply and systematically as possible, and various types of equipment for carrying out the unit operations are described.

High-Speed Internal-Combustion Engine. By H. R. Ricardo. Blackie & Son, Ltd., London and Glasgow, 1931. Cloth, 7 × 10 in., 435 pp., illus., diagrams, charts, tables, 30 s.

A thorough analysis of the scientific basis of design, based upon extensive research and experimentation. General principles, rather than specific designs, are discussed in this important work, which will interest every designer. This is a new edition of the second volume of the "Internal-Combustion Engine." The principal change is the addition of a chapter on the high-speed Diesel engine.

Logic of Science. By Harold R. Smart. D. Appleton & Co., London and New York, 1931. Cloth, 5 × 9 in., 237 pp., 8 s. 6 d.

A systematic discussion of the problems that lie on the borderland between science and philosophy, which endeavors to show what scientific concepts have to contribute to the philosophic problems of existence, value, mind, and reality, and to apply the logical principles developed by philosophy to the discussion of scientific ideas. The aims and scope of natural science are examined, the relation of each science to its neighbors is shown, the emergence of the major problems is traced, and the proposed solutions are indicated.

Metallkeramik. By F. Skaupy. Verlag Chemie, Berlin, 1930. Paper, 6 × 10 in., 60 pp., illus., diagrams, charts, 6 r.m.

This little book is the first to describe systematically the manufacture of articles from powdered metal by molding and sintering it. The preparation and properties of powdered metal and of articles made from it are first described generally. The manufacture of wire, sheet, and molded articles from powdered tungsten, molybdenum, tantalum, and other infusible metals is then treated. This is followed by a section on Carboloy and similar hard alloys. An appendix discusses some other possibilities of the process.

Mikrographie der Buntfarben, Teil 3. Gelbe Eisenoxydfarben; Umbra. (Fachausschuss für Anstrichtechnik, Heft 8.) By H. Wagner, R. Haug and P. G. Hoffmann. V.D.I.-Verlag, Berlin, 1931. Paper, 9 × 12 in., 46 pp., illus., diagrams, charts, tables, 7.50 r.m.

A guide to the practical micrographic examination of the yellow iron pigments and of umber. The chief chemical and physical characteristics are given, and also information concerning the covering ability, drying time, etc., of paints made with these colors.

Modern Sewage Disposal and Hygienics. By S. H. Adams. E. & F. N. Spon, Ltd., London; Spon & Chamberlain, New York, 1930. Cloth, 6 × 9 in., 473 pp., illus., charts, tables, $10.

The experience of English municipalities with various methods of sewage disposal is presented in considerable detail and occupies the major portion of this book. American work at Lawrence and Worcester is also presented, and the requirements of the Minister of Health are given in full. A general summary of the development of sanitation is included and a chronological table of English commissions, legislation, and memorable events affecting sanitation and related questions. Many interesting illustrations are given.

Pocket Book of Engineering Formulae. Thirtieth edition. By Sir G. L. Molesworth. E. & F. N. Spon, Ltd., London, 1931. Leather, 3 × 5 in., 935 pp., diagrams, charts, tables, leather, 6 s.

Considering the price, a remarkable amount of information is contained in this small book, which has been popular among engineers for almost seventy years. In the present revision much new matter has been added, especially upon aircraft, gasoline engines, boilers, and gearing, and the tabular matter has been corrected and brought up to date.

Practical Marine Diesel Engineering. Second edition. By L. R. Ford. Simmons-Boardman Publishing Co., New York, 1931. Cloth, 6 × 9 in., 758 pp., illus., diagrams, charts, tables, $7.

Discusses construction and operation from the point of view of the practical engineer. Theoretical principles are explained briefly, the construction of the various parts of engines and the accessory equipment are described, and a large number of makes of engines are described in detail. A large part of the book is devoted to operation, such matters as repairs, test and lubrication being explained quite fully.

Ship Management and Operation. By H. S. Perry. Simmons-Boardman Publishing Co., New York, 1931. Cloth, 6 × 9 in., 310 pp., illus., diagrams, maps, tables, $4.

Sets forth the duties, functions, and activities of the operating department of a shipping company, with particular emphasis upon the problems involved. Discusses operating organization, personnel management, types of vessels in relation to their cargoes, and the power problem in ship operation. Intended for students of marine transportation and others interested in the management of shipping.

UNDERGROUND SYSTEMS REFERENCE BOOK. By National Electric Light Association. The Association, New York, 1931; 9 × 12 in., 377 pp., illus., diagrams, charts, tables, $4.

A number of leading American authorities have assisted in editing this description of accepted practice in the design, construction, and operation of underground systems of electric distribution. Cables and their insulation, conduit and manhole design and construction, cable installation, splices and terminals, cable operation, etc., are discussed in detail. A bibliography of over four thousand references is appended to the report.

UNTERSUCHUNGEN ÜBER DEN WÄRMEVERBRAUCH DER WOHNUNG. (Reichskuratorium für Wirtschaftlichkeit, RKW-Veröffentlichungen Nr. 65.) By C. Eberle and W. Raiss. V.D.I.-Verlag, Berlin, 1931. Paper, 6 × 8 in., 140 pp., illus., diagrams, charts, tables, 8 r.m.

This monograph is intended to draw the attention of consumers to the possibilities of saving fuel in the household by proper selection and operation of domestic heating plants. Exact data are given on the efficiency and heat losses of the usual types of stoves and furnaces, and the effect of construction, fuel, upkeep, etc., on the losses is shown. The book is based upon practical investigations over several years with dwelling-house plants, supplemented by laboratory researches.

VORTRÄGE AUF DER HAUPTVERSAMMLUNG DER VGB AM 22. April, 1931, in Dresden. (Mitteilungen der Vereinigung der Grosskesselbesitzer E. V., No. 32, pp. 89–193, 31 Mai, 1931.) V.G.B., Berlin. Paper, 8 × 12 in., illus., diagrams, charts, tables, 7 r.m.

Five papers presented at the general meeting of the Boiler Owners' Association in 1931, which discuss in detail matters of importance to power-plant managers. Dr. O. Bauer considers the causes of boiler breakdowns, and Dr. Marguerre reports his experience in operating the high-pressure plant at Mannheim. Dr. Ziegler discusses the effects of corrosion on a 45-atmosphere boiler and the methods of prevention adopted, and Dr. Seyb reports upon an investigation of the effect of alkaline phosphates upon boiler plate. Dr. Sauer describes an extensive investigation of the effect of colloids upon boiler feedwaters.

DIE WERKSTOFFDÄMPFUNG BEI DREH- UND BIEGESCHWINGUNGSBEANSPRUCHUNG. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, Heft 335.) By O. Föppl and G. Schaaf. V.D.I.-Verlag, Berlin, 1930. Paper, 8 × 12 in., 27 pp., charts, diagrams, 4.50 r.m.

Presents the results of an investigation of the damping properties of various metals when subjected to different stresses. Tests of each metal were made by different methods and compared.

Synopses of A.S.M.E. Transactions Papers

THE papers abstracted on this and the following page appear in the current issues of "Aeronautical Engineering" and the Fuels and Steam Power section of A.S.M.E. Transactions. These sections have been sent to all who registered in the similarly named Divisions. Other sections are in the course of preparation and will be announced, when completed, in later issues of "Mechanical Engineering."

AERONAUTICAL ENGINEERING PAPERS

AVIATION NATURAL GASOLINE. By R. C. Alden. [Paper No. AER-53-6]

The usual natural gasoline of commerce is an extremely volatile product and quite unsuitable for direct use as a motor fuel in the conventional fuel systems of today. By careful fractionation, however, it has been found possible to produce "aviation natural gasoline," a fuel that has made a splendid record commercially during the last three years. A considerable amount of research work has been done with regard to this product, and the author discusses it under the following heads: (1) Initial flight tests to determine specification bases for commercial purposes; (2) effects of changes in specifications for aviation natural gasoline; (3) survey of commercial aviation gasolines; (4) flight tests to determine actual temperature in airplane fuel systems; and (5) other investigations. An extensive table of test results of commercial aviation gasolines is included, as well as a bibliography of articles having a bearing on aviation natural gasoline.

COMMERCIAL AIRCRAFT RADIOPHONE COMMUNICATION. By Robert H. Freeman. [Paper No. AER-53-7]

The need of dependable two-way aircraft communication has emphasized the service requirements as they are presented to the pilot. The equipment must be light and yet rugged, and as the essential parts are placed at a distance from the pilot, they must be simple of operation. The paper, without stressing the electrical-engineering side of the air-communication problem, covers the actual mechanical set-up. The mechanical and electrical difficulties encountered in shielding the ignition system and the complete bonding of the ship are discussed in detail. The placement of the component parts for ease of operation is taken up and the subsequent maintenance of the equipment is briefly outlined.

PLYWOOD IN THE AIRCRAFT INDUSTRY. By James R. Fitzpatrick. [Paper No. AER-53-8]

Although plywood is used for nearly all parts of airplanes, its most general use is in wing construction. It is used for wing covering, leading edges, spar webs, gusset plates, cover plates, nose pieces, and tail pieces. The author in this paper tells of joining methods, results from use of plywood in shear, and takes up typical examples of its use in airplane construction.

THE LAYOUT AND DESIGN OF MODERN AIRPLANE PLANTS. By G. W. Plaisted. [Paper No. AER-53-9]

Plants for the manufacture of airplanes are in their design subject to the same general principles as are applied to all factory buildings. They must meet the requirements of straight-line production, flexibility, ample daylight, analysis of material handling, and the special needs of individual departments. Changes in methods of manufacture or changes in conditions should not affect a building so laid out originally as to permit of a flexible straight-line production process, nor affect the maximum return on the investment. The author exhibits the general plant layouts and flow diagrams of four existing airplane plants, and a typical cross-section of an economical factory building that might be converted to airplane manufacturing.

FUELS AND STEAM POWER PAPERS

FLOW CHARACTERISTICS OF SPECIAL FE-NI-CR ALLOYS AND SOME STEELS AT ELEVATED TEMPERATURES. By H. J. French, William Kahlbaum, and A. A. Peterson. [Paper No. FSP-53-9]

In this paper the authors give the results of "creep" tests at different temperatures for three groups of alloys. The eleven metals in the first group included commercial alloys of nickel, chromium,

and iron, both with and without tungsten, and low-chromium steels containing also tungsten, vanadium, or molybdenum. The second group comprised two carbon steels, a $3^1/_2$ per cent nickel steel, and two low-nickel-chromium steels which were tested only at 700 deg. fahr.; the twelve alloys of the third group were melted in a high-frequency induction furnace and their compositions were selected to show the general trends at 1000 deg. fahr. in the load-carrying ability of castings of the nickel-chromium-iron system. A metallographic study of the creep-test specimens revealed intercrystalline weakness in some of the wrought nickel-chromium-iron alloys, especially at temperatures between 1160 and 1390 deg. fahr. A study was also made of the effect of deformation in the creep tests at different temperatures on the hardness and impact resistance of a chromium-vanadium steel at atmospheric temperatures.

Experiences in Chlorinating Condenser Circulating Water. By Vincent M. Frost and W. F. Rippe. [Paper No. FSP-53-10]

This paper gives the experiences of the authors over a period of two years in an endeavor to better the heat transfer and reduce condenser cleaning costs at the Kearny, N. J., power station of the Public Service Electric & Gas Company. The condensing apparatus there consists of five 50,000-sq. ft. condensers of the two-pass type, each having 10,000 one-inch tubes 19 ft. $2^1/_2$ in. long. Chlorine control apparatus was installed, and the paper gives details regarding its operations, and includes water analyses, as well as data on condenser tests, amount of chlorine required, etc. The advantages and disadvantages of chlorination are set forth, together with the reasons for adopting it for the station in question.

Electrical-Conductance Measurements of Water and Steam, and Applications in Steam Plants. By Max Hecht and D. S. McKinney. [Paper No. FSP-53-11]

In this paper a conductance method is presented for determining the concentration of salts in steam-plant water supplies. The method is applied to determine the purity of steam, of supplies used for boiler-feed purposes, and the concentration of boiler and evaporator water. The conductance data are refined by applying both a water and a CO_2 correction. The method for establishing the CO_2 correction is based on the preparation of a standard "synthetic" water, and eliminates the errors accompanying the chemical analysis of "pure" water. The conductance meter used may be calibrated in terms of dissolved salts. The relation of dissolved salts to conductance is discussed. Simple commercial equipment is used for measuring conductance. The data are obtained rapidly by the steam-plant personnel, and the results may be applied easily to the control of water conditions.

Design of Thick-Walled Tubes Subjected to Pressure and Heat Input. By E. W. Luster. [Paper No. FSP-53-12]

With the increases in pressure and oil temperature which have accompanied the development of distillation and cracking equipment in recent years, has arisen the need for a rational method for the design of thick tubes subjected to internal pressure and heat input. The author has accordingly developed in the present paper formulas for temperature and pressure stresses in such tubes, and for calculating the optimum tube for given conditions. Examples of calculations are given, as well as particulars of experimental investigations both completed and contemplated, for the determination of the values of the constants employed in the formulas.

High-Burned Kaolin Refractories. By F. H. Norton. [Paper No. FSP-53-13]

The development of high-fired kaolin refractories is briefly described. The various products made from kaolin such as brick, tank blocks, light-weight brick, and insulators, are discussed from the point of view of their physical characteristics. Also, the service results obtained with these products in typical installations for the past ten years are outlined. The results as a whole show that kaolin, when burned to a sufficiently high temperature, will make a refractory possessing very desirable qualities.

Comparative Physical Properties of Chromium-Nickel, Chromium-Manganese, and Manganese Steels. By C. L. Clark and A. E. White. [Paper No. FSP-53-14]

This paper gives the results of short-time tensile tests at 75 and 1000 deg. fahr., and creep tests at 1000 deg. fahr., on certain selected steels. The steels investigated belong to either the chromium-nickel, the chromium-manganese, or the manganese series. Certain other alloying elements as silicon and tungsten were also present. The chromium-nickel steel specimens were taken from both bar and tube stock, and certain of them were tested in both the hot-rolled and water-quenched conditions.

The results indicate that the substitution of manganese for nickel in chromium-nickel steels is detrimental, at least in so far as the load-carrying ability of the alloy is concerned. Also that while the creep resistance of the manganese and manganese-tungsten steel at 1000 deg. fahr. is superior to that of many pearlitic steels, it is not equal to that of the Enduro KA2 type of alloy.

Properties of Non-Ferrous Alloys at Elevated Temperatures. By C. L. Clark and A. E. White. [Paper No. FSP-53-15]

This paper gives the results of an investigation of the properties of certain non-ferrous alloys at elevated temperatures as determined by short-time tensile and long-time creep tests. The alloys considered are of four groups: the nickel-copper, nickel-cobalt-titanium, copper-zinc, and copper-zinc-tin series. The alloys are tested at temperatures both above and below their lowest temperature of recrystallization.

Results indicate a superiority of the nickel-base alloys over the entire temperature range. The outstanding member of this group is Konel metal, which has short-time tensile properties at 1000 deg. fahr. comparable to Enduro KA2, and the greatest creep resistance at this temperature of any alloy of which the authors are aware. Monel metal retains its properties well up to 800 deg. fahr.

Of the copper-zinc alloys, those containing 70 per cent or more copper are superior to those with 60 per cent of this element. None of these alloys can be used at temperatures much above 400 deg. fahr., and for those containing lower amounts of copper, 300 deg. fahr. is believed to be the maximum working temperature if stresses of appreciable magnitude must be considered.

Fractures in Boiler Metal. By A. E. White and R. Schneidewind. [Paper No. FSP-53-16]

During the past several years many specimens of failed boiler materials have been brought to the authors' attention with questions as to the mechanism and probable causes of the failures. In some cases the pieces consisted of fractured portions of tubes, blow-off pads, saddles, plates, rivets, and similar boiler parts. The examinations, which were to a large extent metallographic in nature, have led to some generalizations and classification of cracks and fractures as related to the causes of failure. This paper classifies the types of failure and gives their metallographic characteristics. The material presented consists of a short review of the literature on boiler-metal failures, a detailed description of fractures in boiler metal due to known causes, and a description of actual failures in service.

NOTE: Those who have not registered in the A.S.M.E. Aeronautic and Fuels and Steam Power Divisions, whose papers are abstracted on this and the preceding page, and who desire copies of any of these papers, may obtain them by using the form given below.

To the Secretary, A.S.M.E., 29 West 39th Street, New York, N. Y. Date........................

Please send copies of paper checked below:

Aeronautical Engineering [AER-53-6] [AER-53-7] [AER-53-8] [AER-53-9]

Fuels and Steam Power [FSP-53-9] [FSP-53-10] [FSP-53-11] [FSP-53-12] [FSP-53-13] [FSP-53-14] [FSP-53-15] [FSP-53-16]

PRINT name (Important) ....

Street Address...City........................

Current Mechanical Engineering Literature

Selected References From The Engineering Index Service

(The Engineering Index Service Is Registered in the United States, Great Britain, and Canada by the A.S.M.E.)

THE ENGINEERING INDEX SERVICE furnishes to its subscribers a Weekly Card Index of references to the periodical literature of the world covering every phase of engineering activity, including Aeronautic, Chemical, Civil, Electrical, Management, Mechanical, Mining and Metallurgical, Naval and Marine, Railway, etc. Of the many items of particular interest to mechanical engineers a few are selected for presentation each month in this section of "Mechanical Engineering." In operating The Engineering Index Service, The American Society of Mechanical Engineers makes available the information contained in the more than 1800 technical publications received by the Engineering Societies Library (New York), thus bringing the great resources of that library to the entire engineering profession. At the end of the year all references issued by the Service are published in book form, this annual volume being known as The Engineering Index.

Photoprint copies (white printing on a black background) of any of the articles listed in the Index may be obtained at a price of 25 cents a page. When ordering photoprints identify the article by quoting from the index item: (1) Title of article; (2) Name of periodical in which it appeared; (3) Volume, number, and date of publication; (4) Page numbers. A remittance of 25 cents a page should accompany the order. Orders should be sent to the Engineering Societies Library, 29 West 39th Street, New York.

AERODYNAMICS

Turbulence. A Suggested Method for Measuring Turbulence, C. F. Taylor. Nat. Advisory Committee for Aeronautics—Tech. Notes, no. 380, June 1931, 7 pp., 4 figs. Desirability of quantitative measure of turbulence and possible methods of attack; hot-wire anemometer as instrument for measuring turbulence; apparatus consisting essentially of two hot wires, one parallel to air flow and one at right angles to it. Bibliography.

AERONAUTICAL INSTRUMENTS

Air-Speed Indicators. Einfluss der Zahigkeit bei Geschwindigkeitsmessungen mit Standruckmultiplikatoren (Influence of Viscosity in Air Speed Measurement With Dynamic Pressure Multiplicator), H. Peters. Zeit. fuer Flugtechnik und Motorluftschiffahrt, vol. 22, no. 11, June 15, 1931, pp. 321–323, 7 figs. Results of tests conducted at Goettingen; vacuum wind tunnel with Bruhn venturi double nozzle; Reynolds number does not change after reaching sound velocity in spite of increased speed; graph illustrates multiplication factor as function of Reynolds number for different pressures and temperatures.

AIRPLANE CARRIERS

Catapulting Equipment. The R.A.E. Land-Type Catapult. Aeroplane, vol. 40, no. 21, May 27, 1931, pp. 974 and 976, 3 figs.; see also Flight, vol. 23, no. 22, May 29, 1931, pp. 469–471, 5 figs. Catapulting equipment of Royal Air Force reducing take-off distance of bombers from 300 to 33 yd.; catapult operates by revolving cable round drum and so pulling aeroplane forward at about 60 m.p.h. for 100 ft. in three sec.; motive power provided by compressed air engines of 4000 hp.

AIRPLANE ENGINES

Alfa Romeo. Le perfette costruzioni motoristiche per l'aviozione dell'Alfa Romeo (Perfect Engine Construction for Aircraft of Alfa Romeo). L'Ala d'Italia, vol. 10, no. 5, May 1931, pp. 347–349, 8 figs. Features of Alpha Romeo D with compressor; Mercurius with compressor and reduction gear, developing 550 to 840 hp.; 2 types of Jupiter, and Lynx build under Bristol license.

Diesel. Der Statax-Halbdiesel-Flugmotor (Statax Semi-Diesel Airplane Engine), F. Hansen. Schweizer Aero Revue, vol. 6, no. 10, May 15, 1931, pp. 133–135, 2 figs. Operating principles of Diesel radial air-cooled 3-cylinder engine with fuel injection; bore and stroke 80 by 80 mm.; each cylinder has individual crankshaft which is geared to centrally located propeller shaft; gas oil consumption 20 g/PSh.

Pobjoy. The Pobjoy "R" Type Engine. Flight, vol. 23, no. 23, June 5, 1931, pp. 496–498, 5 figs. Design and performance data of 7-cylinder air-cooled radial engine having passed British Air Ministry type tests; o.a. diam. 647 mm., weight 130 lb.; normal power of 75 b.hp. at speed of 3000 r.p.m., while reduction gearing reduces corresponding propeller speed to 1400 r.p.m.; bore 77 mm., and stroke, 87 mm.

AIRPLANES

Brakes. Versuche mit Flugzeugbremsen (Experiments With Airplane Brakes), F. Michael. Zeit. fuer Flugtechnik und Motorluftschiffahrt, vol. 22, no. 10, May 28, 1931, pp. 302–312, 24 figs. Design of brakes for large airplanes; self-energizing effect of brakes with internal shoes; measurements for determining brake effect.

Aeroplane Braking Systems, R. Waring-Brown. Aircraft Eng., vol. 3, no. 28, June 1931, pp. 139–140, 9 figs. Survey of problem of fitting wheel brakes and types at present in use; provision for torque reaction; effect of wheel position on braking; graphs illustrate calculation of stopping distance; drag in terms of machine weight; wheel loads for various values of vertical wheel travel.

Design. Grapho-Analytical Method of Least Work, E. Tousingnan and W. E. Koneczny. Airway Age, vol. 12, no. 10, June 6, 1931, pp. 572–575 and 602, 9 figs. Simplifying solution of statically indeterminate structures by employing method of graphic analysis; necessity of expressing analytically loads in members of structure in terms of load in redundant member is eliminated.

Flugmechanische Beziehungen zwischen Fluggeschwindigkeit, Flugkosten und Flugweite und ihre Abhaengigkeit von der Widerstandsflaeche des Flugzeuges (Relations Between Flying Speed, Flying Costs, and Flying Range With Particular Regard to Influence of Drag Surface of Airplanes), A. Koyemann. Zeit. fuer Flugtechnik und Motorluftschiffahrt, vol. 22, no. 11, June 15, 1931, pp. 329–332. Interpretation of formulas for numbers of merit, and their application to representative designs; calculation of minimum speed for most economical operation, not in order to save time, but for aerodynamic reasons.

Azione d'impennaggio ed effetti d'elica (Action of Tail Plane and Effect of Propeller), G. A. Giulio Andreoli. Notiziario Tecnico di Aeronautica, vol. 6, no. 12, Dec. 1930, pp. 219–234. Mathematical analysis of interaction of wing and tail plane on one hand, and airplane and propeller on other hand.

Calcolo di verifica dei longheroni di spruce consezioni a I o a cassetta (Check Calculation for Spruce Bars With I Sections), A. Mori. Notiziario Tecnico di Aeronautica, vol. 6, no. 12, Dec. 1930, pp. 235–238, 3 figs. Interpretation of test results with graphs simplifying calculations for bending and compression; reference to American practice.

Maintenance and Repair. Repairing and Service for Airplanes, G. N. Kramer. Airway Age, vol. 13, no. 1, July 4, 1931, pp. 30–32, 3 figs. Hangar layout and service equipment of Arbogast Aero Service; at Long Beach, Calif., Municipal Airport.

Manufacture. Nietverfahren im Metall-Flugzeugbau (Riveting in Metal-Airplane Construction), W. Pleines. Hauszeit. der V.A.W. u.d. Erftwerk A.G. fuer Aluminium, vol. 3, no. 4–6, Apr.-June 1931, pp. 166–173, 22 figs. Indexed in Engineering Index 1930, p. 54, from Luftfahrtforschung, Apr. 30, 1930, and from Nat. Advisory Committee for Aeronautics, no. 596, 597, and 598, 1930.

Materials—Corrosion. La corrosione dei materiali impiegati nelle costruzioni aeronautiche (Corrosion of Materials Used in Aeronautical Construction), G. Guidi. Ingegnere, vol. 5, no. 3, Mar. 1931, pp. 153–163, 23 figs. Observations on corrosion of hulls, seaplanes, aircraft, tanks, etc.; corrosion of samples of metallic alloys used in airplane construction, when exposed to action of seawater.

Propellers. Full-Scale Tests of Metal Propellers at High Tip Speeds, D. H. Wood. Nat. Advisory Committee for Aeronautics—Report, no. 375, 1931, 22 pp., 33 figs. Tests of 10 full-scale metal propellers of several thickness ratios at various tip speeds up to 1350 ft. per sec.; no loss of efficiency up to tip speeds of approximately 1000 ft. per sec.; above this tip speed loss is at rate of about 10 per cent per 100 ft. per sec. increase relative to efficiency at lower speeds for propellers of pitch diam. ratios 0.3 to 0.4.

Comparison of Full-Scale Propellers Having R.A.F.-6 and Clark Y Airfoil Sections, H. B. Freeman. Nat. Advisory Committee for Aeronautics—Report no. 378, 1931, 20 pp., 20 figs. Efficiencies of two series of propellers having sections with thickness chord ratios of 0.06, 0.08, and 0.10; R.A.F.-6 sections gave about same maximum efficiency as Clark Y propellers and were more efficient for conditions of climb and take-off.

Tailless. The Westland-Hill Pterodactyl Mark IV. Aeroplane. Engineer, vol. 151, no. 3937, June 26, 1931, p. 706, 1 fig. Tailless airplane, 3-seater cabin machine, fitted with De Havilland Gipsy III engine; primary object of design is attainment of higher degree of safety, comfort, and performance than is possible with conventional type of aircraft.

Wheels. Static, Drop, and Flight Tests on Musselman Type Airwheels, W. C. Peck and A. P. Beard. Nat. Advisory Committee for Aeronautics—Report, no. 381, 1931, 20 pp., 20 figs. Quantitative information on shock-reducing and energy-dissipating qualities of set of 30 by 13-6 Musselman type airwheels; tests showed that walls of tires carried considerable portion of load, each tire supporting load of 600 lb. with depression of approximately 6 in.; shock-reduc-

ing quantities, under severe tests, and energy-dissipating characteristics of tires, under all tests, were poor.

Wings. Abwindmessungen hinter Tragfluegeln mit abgerissener Stroemung (Downwash Measurements Behind Wings for Interrupted Flow), E. Petersohn. Zeit. fuer Flugtechnik und Motorluftschiffahrt, vol. 22, no. 10, May 28, 1931, pp. 289–300, 32 figs. Test set-up and investigations to show that low pressure field due to interruption of continuous flow, seems to be fairly independent of wing profile as far as extent and direction are concerned.

Untersuchungen ueber Flugzeuge mit veraenderlichen Flachen (Investigation of Airplanes With Variable Surfaces), W. Schmeidler. Zeit. fuer Flugtechnik und Motorluftschiffahrt, vol. 22, no. 11, June 15, 1931, pp. 325–329, 3 figs. Mathematical analysis of lift and induced drag of wing surface with variable camber; change of profile is effected in design developed at University of Breslau, by embodying sliding surface in center part of wing for improving landing and take-off performance.

Variable Lift Wings, F. Duncanson. Flight, vol. 23, no. 25, June 19, 1931 (supp.), pp. 556a-556d, 12 figs. Investigation of variable camber wings illustrates that with modern efficient aircraft advantages derived from use of variable camber are greater than they were in older types of machine; variable camber will permit top-speed of 12 m.p.h. greater than that of fixed wing machine, at same time improving rate of climb, and service and absolute ceiling.

ALLOYS

Aluminum. See ALUMINUM ALLOYS.

Castings. See CASTINGS, High Temperature.

Steel. See COPPER-NICKEL STEEL.

Density Testing. Les essais des alliages à la densité (Testing Density of Alloys), R. Eck. Pratique des Industries Mécaniques, vol. 14, no. 3, June 1931, pp. 107–111, 1 fig. Density tests which may be used, not to replace chemical analysis, but as process of control in manufacture; methods of test and results; light alloys of aluminum and copper; lead-tin and lead-antimony alloys; tungsten steel.

ALUMINUM

Sheet—Properties. Untersuchungen ueber den Einfluss verschiedener Zwischengluehtemperaturen auf die technologischen und chemischen Eigenschaften von Aluminiumblech (Investigations of Influence of Different Intermediate Annealing Temperatures on Technological and Chemical Properties of Aluminum Sheet), H. Roehrig. Hauszeit. der V.A.W. u.d. Erftwerk A.G. fuer Aluminium, vol. 3, no. 4–6, Apr.-June 1931, pp. 237–238. Report from materials testing laboratory of Lauta Works.

Welding. Das Schweissen von Aluminium (Welding of Aluminum). Autogen Schweisser, vol. 4, no. 1, Jan. 1931, pp. 1–4, 4 figs. Welding methods and precautions in joining heavy gage aluminum sheets.

Das Schweissen des Aluminiums and seiner Legierungen (Welding of Aluminum and Its Alloys), F. Goldmann. Hauszeit. der V.A.W. u.d. Erftwerk A.G. fuer Aluminium, vol. 3, no. 4–6, Apr.-June 1931, pp. 142–147, 8 figs. Application of welding to aluminum sheet, wire, sections, pipe, etc.; gas, gas-fusion, electric arc and electric resistance welding.

Die Schweissbarkeit des Aluminiums (Welding Properties of Aluminum), H. Holler. Hauszeit. der V.A.W. u.d. Erftwerk A.G. fuer Aluminium, vol. 3, no. 4/6, Apr.-June 1931, pp. 123–133, 22 figs. Development of different aluminum welding methods and nature and limits of welding application; strength values of welded aluminum sheets; gas fusion welding.

ALUMINUM ALLOYS

Castings. Korrosion von Aluminium-Gusslegierungen (Corrosion of Aluminum Alloy Castings), W. Kroenig. Korrosion und Metallschutz, vol. 7, no. 5, May 1931, pp. 104–108, 10 figs. Report on investigations carried out at Materials Department of Central Aerodynamic and Hydrodynamic Institute, Moscow; results of mechanical tests and metallographic analysis; corrosion tests; seawater corrosion; alloys with copper showed poor resistance to corrosion; manganese additions gave more favorable results.

Production of an Aluminium-Alloy Casting, E. Jackson. Foundry Trade Jl., vol. 44, no. 772, June 4, 1931, p. 392. Chief metals used for alloying with aluminum are zinc, magnesium, manganese, and copper, also metalloid silicon; molding practice; pouring; feature of aluminum alloy castings is that they should not be left in mold too long after casting. Before Inst. Brit. Foundrymen.

Welding. Die Schweissbarkeit der Aluminium-Legierungen in Abhaengigkeit vom Legierungstypus (Welding Properties of Aluminum Alloys in Relation to Type of Alloy), E. Scheuer. Hauszeit. der V.A.W. u.d. Erftwerk A.G. fuer Aluminium, vol. 3, no. 4–6, Apr.-June 1931, pp. 134–138, 12 figs. Fusion welding, gas fusion welding and electric welding methods and their application to aluminum-copper, aluminum-zinc-copper, and aluminum-silicon alloys.

APPRENTICES

Training. Start Apprentice Training Now, C. J. Freund. Iron Age, vol. 127, no. 25, June 18, 1931, pp. 1957–1960. Period of depression considered best time to start program; reasons given.

AUTOGIROS

Commercial. Three Commercial Autogiros. Aviation, vol. 30, no. 7, July 1931, pp. 408–415, 14 figs. Comparative study of proportions and design of Pitcairn and Kellet machines.

B

BEARINGS

Roller. Ueber die Tragfaehigkeit von Zylinderroellenlagern (Load Capacity of Cylindrical Roller Bearings), R. Mundt. Maschinenbau, vol. 10, no. 10, May 21, 1931, pp. 354–357, 4 figs. Relation between life and permissible load; definition of specific stress; deviation of fatigue test results for determining life; check calculation for load data of 4 representative manufacturers; definition of requirements for load data.

[See also LOCOMOTIVES, Roller Bearings.]

BELT DRIVE

Experiments. Données expérimentales sur le glissement des courroies (Slipping of Belts), M. Swyngedauw. Revue de l'Industrie Minérale, no. 252, June 15, 1931, pp. 215–221, 2 figs. Results of author's experiments with number of different makes of belts, based on two papers, one on belt slip, to be published in Bulletin de la Société des Ingénieurs Civils de France, and one on loss of energy, etc., indexed in Engineering Index 1929, p. 177, from Revue Générale de l'Electricité, Oct. 18, 1929; author's experiences demonstrate advisability of using pulley of sufficiently large diameter, to permit linear belt speed of 20 to 30 m. per sec.

BOILER FURNACES

Design. The Combustion Space—I and II, F. J. Matthews. Power Engr., vol. 26, nos. 302 and 303, May 1931, pp. 183–185, and June, pp. 226–228, 13 figs. May: Practical discussion of design factors; combustion of gases in fuel bed and combustion space; size of combustion space; table of yields from distillation of British coals; test results showing relation between required size of combustion space, given completeness of combustion, and percentage of excess air; relation between size of combustion space required and chemical properties of coal. June: Boiler furance design with special reference to settings and baffles; test results of various settings.

Refractory Materials. Ausmauerung des Feuerraumes von Wasserrohrkesseln (Furnace Lining of Water-Tube Boilers), H. Schlicke. Brennstoff und Waermewirtschaft, vol. 13, no. 5, May 1931, pp. 77–79, 1 fig. Chemical influences of slag on refractory lining; proper roof construction; brick of high resistance at maximum temperatures.

Refractories in Boiler House Practice, H. N. Bassett. Eng. and Boiler House Rev., vol. 44, no. 12, June 1931, pp. 774, 776, 778 and 780. Requirements of good refractory; resistance to abrasion and erosion; slagging; silicon carbide; spalling; strength of firebrick.

Refractories for Boiler Furnaces, W. J. Rees. Eng. and Boiler House Rev., vol. 44, nos. 10 and 11, Apr. 1931, pp. 652 and 655–656, and May, pp. 708–710, 7 figs. Previously indexed from Iron and Coal Trades Rev., Jan. 2, 1931.

BOILER PLATES

Cracking. Accelerated Cracking of Mild Steel Under Repeated Bending, W. Rosenhain and A. J. Murphy. Iron and Coal Trades Rev., vol. 122, no. 3302, June 12, 1931, p. 951. Discussion of paper previously indexed from various sources.

BOILERS

Corrosion. Some Suggestions Regarding Harmonious Relationship Between Boiler Water and Metal, R. E. Hall. Combustion, vol. 2, no. 11, May 1931, pp. 40–45, 1 fig. Types of boiler metal corrosion, conditions that cause or contribute to their occurrence, and methods of prevention, both chemical and mechanical; circumstances of several cases of corrosion and means used in each case to correct condition; maintenance of correct pH value, known as rate-factor in corrosion, and removal of dissolved oxygen, quantity-factor are given as two principal requisites to solution of corrosion difficulties. Before Am. Soc. Mech. Engrs.

Design. Gennevilliers Installs Single-Pass Fin-Tube Boilers. Power, vol. 73, no. 24, June 16, 1931, pp. 954–956, 3 figs. Design, construction, and operating features or Rauber-Luquet units which combine compactness, good circulation and low first cost; fins used on superheater tubes; supplementary data on Rauber-Luquet boilers.

The Development of Steam Generating Plants, C. H. Davy. Rugby Eng. Soc.—Proc., vol. 25, part 1, 1930–1931, pp. 1–16 and (discussion) 17–22. Limitations of early steam-producing plants which resulted in introduction of water-tube boiler; chief difficulties met with in shell-type boiler.

Firing. Hochleistungsfeuerungen (High-Capacity Boiler Furnaces), O. Nerger. Feuerungstechnik, vol. 19, no. 6, June 15, 1931, pp. 92–95, 4 figs. Development of new firing systems to meet modern conditions; Lopulko and Fuller pulverized-coal systems; combustion chamber; comparison between pulverized-coal systems in America and Europe; comparison of piece-coal and pulverized-coal firing; radiation boilers.

High Pressure. La chaudière Loffler dans les installations fixes, les installations marines et les chemins de fer (Loeffler Boiler in Stationary, Marine and Railroad Installations), F. Englert. Génie Civil, vol. 98, no. 23, June 6, 1931, pp. 568–570, 4 figs. Advantages of high pressure and high-temperature steam with particular regard to operating economy in plant of various capacities.

Die Speicherfaehigkeit der Hockdruckkessel (Storage Capacity of High-Pressure Boilers), G. Roehrich. Archiv fuer Waermewirtschaft, vol. 12, no. 6, June 1931, pp. 179–181. Storage capacity of boilers of over 100 atmos. pressure cannot be increased by water space, but by steam space and by content of superheater and steam pipe lines; tables for calculation of storage capacity.

Locomotive. See LOCOMOTIVES, High Pressure.

Pulverized Coal. Die Kohlenstaubfeuerung fuer Dampfkessel und ihre Grundlagen in Oesterreich (Principles of Pulverized Coal-Firing for Steam Boilers and Its Use in Austria), P. Krebs. Sparwirtschaft, vol. 9, no. 3, Mar. 1931, pp. 97–107, 10 figs. Various types of pulverized coal-fired boiler installations, with particular regard to automatic operating facilities for stoker; data on operating economy and cost of imported coal.

Welding. Boiler Manufacturers Discuss Welding at Annual Meeting. Boiler Maker, vol. 31, no. 6, June 1931, pp. 151–157. Application of fusion welding to construction of boilers and pressure vessels discussed at convention of American Boiler Manufacturers' Association; charts summarizing production of steel boilers from 1919 to 1930 inclusive; smoke prevention conference committee; cost accounting committee report; auxiliary equipment; work of feed-water studies committee; report of welding committee and discussion.

BOLTS AND NUTS

Manufacture. Moegliche und zweckmaessige Gueteanforderungen und ihre Steigerung durch die Massenerzeugung (Quality Requirements and Improvement by Mass Production), K. Schmiz. Stahl und Eisen, vol. 51, no. 24, June 11, 1931, pp. 729–734, 16 figs. Quantity production and its relation to requirements of manufacturing industry; cooperation between materials producer and manufacturer who uses materials; necessity for control of product; information given is based on experience of Bauer and Schaurte, manufacturers of bolts and nuts.

BUSINESS CONDITIONS

Stabilizing. The Problem of Stabilizing Business, F. Parker. Engrs. and Eng., vol. 48, no. 6, June 1931, pp. 121–124. Program for stabilization of business includes: maintenance of existing standards of living; coordination of activities of individual business enterprises in same line of trade or industry, through coherent, unified program devised and executed by national and local trade associations; and sympathetic cooperation between business, banks, and government, grounded upon concept of world business, as distinguished from existing provincialism of national business.

C

CABLEWAYS

Passenger. Die Gipfelstrecke der Bayerischen Zugspitzbahn (Summit Stretch of the Bavarian Zugspitz Railroad), E. von Willmann. Zentralblatt der Bauverwaltung, vol. 51, no. 15, Apr. 15, 1931, pp. 236–239, 8 figs. Description of passenger cableway carrying passengers from Schneefernerhaus Hotel, at end of rack railway, to top of mountain 700 m. off and 279 m. higher; trip is made in three minutes; cableway is equipped with polygonal cages carrying maximum of 25 passengers.

CASE HARDENING

Carburizing. Case Hardening With Liquid Carburizing Agent. Engineering, vol. 131, no. 3414, June 19, 1931, p. 803, 1 fig. Method of case carburizing employing carburizing medium termed Carbonal, liquid having vegetable base and rich in hydrocarbons; process has been developed by Hevi Duty Electric Co., Milwaukee.

CASTINGS

High Temperature. Cast Alloys for High-Temperature Service, D. Hanson. Foundry Trade Jl., vol. 44, no. 772, June 4, 1931, pp. 387–390. Theory underlying use of metals at high temperatures; scaling of iron; chemical resistance and mechanical strength at high temperatures; principles of alloying in relation to mechanical strength; futility of accelerated tests; incidence of plasticity; where castings equal wrought material. Before Inst. Brit. Foundrymen.

CAST IRON

Heat Conductivity. The Thermal Conductivity of Cast Iron Between 0 and 100 deg. C., H. Thyssen, J. R. Marechal and P. Lenaerts. Foundry Trade Jl., vol. 44, no. 773, June 11, 1931, pp. 405–407, 5 figs. Theoretical principles of heat transmission; modified Despretz method of determining relative conductivities; conductivity is higher with increasing phosphorus content and with diminishing diameters of bars; size of graphite lamellae is proportionate to diameter of bars. Before Inst. Brit. Foundrymen.

CHAINS

Wrought Iron. Research on Wrought-Iron Chains. The Nature of Defective Laminations in Wrought-Iron Bars and Chain Links, H. J. Gough and A. J. Murphy. Iron and Coal Trades Rev., vol. 122, no 3297, May 8, 1931, pp. 731–734, 8 figs. Paper before Iron and Steel Inst., previously indexed from Engineering, May 15, 1931.

CHROMIUM PLATING

New Methods. Industrial Chromium Plating, D. H. Bissell. Melliand, vol. 3, no. 3, June 1931, pp. 240–243, 3 figs. Development of new plating methods and equipment during past few years.

COAL

Classification. Some Notes on Fuel Technology and the Classification of Coal, C. A. Seyler. Gas Engr., vol. 48, no. 5, May 1931, pp. 269–271, 4 figs. Complex chart of coal classification, with explanation of use; calorific values of coal can be represented by series of parallel straight lines, each representing coals of same gross calorific power and called isocals; volatile matter represented by lines called isovals; chart enables combustion engineer to obtain all data he needs to degree of accuracy sufficient for most practical purposes. Before Inst. Fuel.

Cleaning. Notes on Washing vs. Dry Cleaning (Peale-Davis Method) of Parkgate Coal, N. E. Webster. Instn. Min. Engrs.—Trans., vol. 81, pt. 2, May 1931, pp. 175–183 and (discussion) 183–189 and 202–203, 1 supp. plate at end of journal. Previously indexed from Colliery Guardian, Mar. 27, Apr. 2 and 24, 1931, and Iron and Coal Trades Rev., Mar. 27, Apr. 10 and 24, 1931.

Recent Developments in Coal Cleaning, R. Lessing. Eng. and Boiler House Rev., vol. 44, no 12, June, 1931, pp. 782, 784, 786, and 788. Paper previously indexed from Chem. and Industry, Jan. 30, 1931.

Combustion. L'équilibre entre le carbone et ses oxydes (Equilibrium Between Carbon and Its Oxides), P. E. Henry. Annales des Mines, vol. 19, no. 1, Jan. 1931, pp. 5–25, 2 figs. Direct and indirect determination of equilibrium; comparison of different determinations; influence of pressure on equilibrium; numerical data.

Constituents. A Microscopical and X-Ray Study of Pennsylvania Anthracite, H. G. Turner and H. V. Anderson. Indus. and Eng. Chem., vol. 23, no. 7, July 1931, pp. 811–815, 14 figs. Pennsylvania anthracite is composed of three constituents, anthraxylon, attritus, and fussain; knowledge of constitution of coal as revealed under microscope is necessary to correct interpretation of X-ray analyses; this is shown by fact that diffraction patterns of constituents of anthracite show marked differences; attritus contains almost all mineral matter of anthracite, as shown by radiographs and sharp Debye-Scherrer rings in attritus diffraction pattern. Before Am. Chem. Soc.

Mines and Mining. Machine Loading Meets Tests in Ohio Under Adverse Natural Conditions, A. F. Brosky. Coal Age, vol. 36, no. 4, Apr. 1931, pp. 171–173 and 187, 8 figs. partly on p. 170. Three mines of Wheeling and Lake Erie Coal Mining Company, operating Pittsburgh no. 8 seam; equipment, underground layout, crew organization, and performance; data on time studies; 17 workers in 10 rooms produced 300 tons in 8 hours from 5 ft. coal seam with 1 ft. drawslate.

Preparation. Modern Preparation—Have Mid-West Fields Met Test of Consumer Demand? H. B. Cooley and J. A. Garcia. Coal Age, vol. 36, no. 6, June 1931, pp. 315–316, 4 figs. Ways in which impurities have been eliminated at time coal is being loaded in Illinois and Indiana mine; washing plants established at some mines; comparison of trend in washing of coal in Illinois, Indiana, and West Virginia fields; screen and ash analyses of Franklin County dub or fine coal. Before Mid-West Bituminous Coal Conference.

Progress in. Les progrès réalisés depuis 50 and dans l'utilisation de la houille comme combustible (Progress Realized During 50 years in Utilization of Coal as a Combustible), A. Fichet. Génie Civil, vol. 98, no. 22, May 30, 1931, pp. 546–547. Historical review of development and equipment including gas producers, mechanical stokers, use of pulverized carbon, rotary furnaces, etc.

Pulverized Firing. A Tangential-Firing Pulverized Fuel System. Power Engr., vol. 26, no. 302, May 1931, pp. 172–174, 4 figs. Design and operating features of systems employing vertical cylindrical gasifying chamber; layout of boiler plant at Stewart and Lloyds Coatbridge Mills, equipped with Duffield system of pulverized-fuel firing.

Pulverized, Hydrocarbon Absorption. The Absorption and Retention of Hydrocarbons by Solid-Fuels—Part II, B. Moore. Fuel, vol. 10, no. 6, June 1931, pp. 244–253, 10 figs. Experiments to provide information on solid fuels in powdered form for hydrocarbons; pentane, hexane, heptane, octane, nonane, and decane; absorption and retention of hydrocarbons does not affect capacity of fuel for absorbing water vapor.

COKE PLANTS

Materials Handling. See MATERIALS HANDLING, In Coke Plants.

COPPER-NICKEL STEEL

Corrosion. The Resistance of Copper-Nickel Steels to Sea Action, J. N. Friend and W. West. Engineering, vol. 131, no. 3413, June 12, 1931, p. 774. Study of combined influence of copper and nickel; forged alloys suffered slightly greater corrosion than corresponding annealed bars; presence of nickel greatly refines structure of cast steel, but there is no evidence that copper does so likewise. Before Iron and Steel Inst.

CUTTING TOOLS

History. Cutting Materials Yesterday and Tomorrow; A. G. Baumgartner. Am. Mach., vol. 74, no. 25, June 18, 1931, pp. 929–932, 3 figs. History of cutting tools indicates that periodic evolution rather than gradual development has characterized metal-working history.

[See also TUNGSTEN CARBIDE.]

D

DIESEL-ELECTRIC POWER PLANTS

For Power. The Diesel Engine as a Prime Mover for Cheap Power Supply. Machy. Market, no. 1599, June 26, 1931, p. 19. Choice of power supply; conditions prior to grid scheme; proof of reliability is shown in increasing number of Diesel engines being used for marine propulsion; cost of power from Diesel engine; cost of electric motor.

DIESEL ENGINES

Automotive. Progress in the Application of the Diesel or Heavy Oil Engine to Road Transport, W. H. Goddard. World Power, vol. 15, no. 89, May 1931, pp. 382–384 and 387. Design of Diesel engine for road transport; new all-British engine already in use in passenger vehicle; fuel prices; fuel and lubricating oils.

Compressorless. Thomassen verticale compressorlooze Dieselmotor (Thomassen Vertical Compressorless Diesel Engine), P. C. Brunting. Ingenieur, vol. 46, no. 24, June 12, 1931, pp. W79–W81, 4 figs. New type developed by Thomassen Motor Works, Arnhem, Holland; engines are made up to 8-cylinders maximum and develop 50 hp. per cylinder; cross-sectional drawings are given.

Design. Improvements in Diesel Cylinder Head Design. Diesel Power, vol. 9, no. 5, May 1931, pp. 228–229, 4 figs. Review of principles which have been applied to recent improvements in cylinder head design; design features of De La Vergne Diesel cylinder head.

Fuel Injection. The Quiescent Combustion Chamber, J. A. Spanogle. Am. Soc. Mech. Engrs.—Advance Paper, for mtg. June 23–26, 1931, 7 pp., 10 figs. Performance tests of single-cylinder test unit with combustion chamber that seems best suited to operation without effective air flow in combination with round hole injection orifice; in more than 800 hr. of engine operation no failures or replacements; maximum cylinder pressures less than 800 lb. per sq. in.; supercharging pressures slightly over 1000 lb. per sq. in. Bibliography.

Fuels. Fuel Testing in Slow and High Speed Diesel Engines, L. J. Le Mesurier and R. Stansfield. Petroleum Times, vol. 25, no. 636, Mar. 21, 1931, pp. 409–410. Research on problems presented directly by engine users and toward fundamental aspects of combustion; list of 14 types of fuels; technical data and operating characteristics of Petter, Junkers, McLaren Benz, and Robey engines; relative specific fuel consumption by weight under various conditions; knocking of motor fuels in spark ignition engine. Before Instn. Petroleum Technologists.

High Speed. Schnellaufende Dieselmotoren (High Speed Diesel Engines), W. Laudahn. Glasers Annalen, vol. 108, nos. 10 and 12, May 15, 1931, pp. 163–166, and June 15, pp. 179–185, 24 figs. Definitions of term "high-speed;" comparison with steam and carburetor engines; analysis of prerequisites for high speed of Diesel engines; general design of high-speed Diesel engines; combustion processes, fuel pumps and nozzles; pistons; bearings and lubrication; balancing problems and damping of oscillations; increasing output by supercharging; reliability.

Lubrication. Making the Most of the Oil Film in Diesel Bearing Lubrication, E. T. Adams. Diesel Power, vol. 9, no. 5, May 1931, p. 246. Application of wedge-film principle illustrated with sketches.

Maintenance and Repair. Diesel Engine Upkeep—XIII. Power Plant Eng., vol. 35, no. 12, June 15, 1931, pp. 653–656, 9 figs. Fuel troubles; methods of removing foreign matter from fuel oil; fuel pump types and methods of adjustment; distribution systems.

Maybach. Maybach-Motorenbau (Maybach Engine Manufacture), K. Maybach. Werft Reederei Hafen, vol. 12, no. 11, June 1, 1931, pp. 205–206, 5 figs. Types of Maybach Diesel engines for marine and automotive propulsion; compressorless Diesel engines; history of development.

Multi-Cylinder. The Development of the Multi-Cylinder Horizontal Oil Engine, A. C. Yeates. Diesel Engine Users Assn.—Paper, no. S.100, for mtg. Feb. 19, 1931, pp. 1–33 and (discussion) 35–46, 32 figs. Previously indexed from Mech. World, Apr. 3, 10, 17, and 24, 1931.

New. The 300-Hp. Speedway Light-Weight Diesel Engine. Motive Power, vol. 2, no. 6, June 1931, pp. 29 and 45, 2 figs. New model light-weight oil engine, adaptable for portable and semi-portable industrial application manufactured by Consolidated Shipbuilding Corp., Morris Heights, New York, N. Y.; 4-stroke cycle, mechanical-injection, direct-reversible type, developing 300-hp. at 700 r.p.m.; six-cylinders with bore of $8^1/_2$ in. and stroke of 11 in., which gives piston displacement of 3745 cu. in.; net weight of complete engine is 7600 lb., which is 25.3 lb. per b.hp. and 2.03 lb. per cu. in. of piston displacement

Supercharging. Les possibilités extremes actuelles du moteur Diesel à 4 temps suralimenté (Possibilities of Supercharged 4-Stroke Diesel Engines), Gautier. Revue des Combustibles Liquides, vol. 9, no. 85, May 1931, pp. 204–215, 4 figs. Results of investigation of single-acting supercharged engine; characteristics of turbo-compressor; comparison of supercharging with single and with multiple turbo-compressors; advantages of supercharging.

Temperature Measurements. Direct Measurements of Oil Film Temperatures on Diesel Piston Rings, E. H. Hillman. Diesel Power, vol. 9, no. 5, May 1931, pp. 226–227, 3 figs. Testing equipment and procedure in de-

termination of piston ring temperature; fusible-plug indications of ring temperatures; fusible alloy melting points; test results; table of Diesel piston ring temperatures.

DIESEL LOCOMOTIVES

See LOCOMOTIVES, Diesel.

E

ECONOMIZERS

Ribbed Tube. Schneken-Rippenrohr-Ekonomiser (Spiral Ribbed-Tube Economizer), E. Praetorius. Waerme, vol. 54, no. 23, June 6, 1931, pp. 433–437, 11 figs. Role of economizer in modern plant; smooth and ribbed-tube economizers; relation of heating to flue-gas and feed-water temperature; acceptance tests and their evaluation.

ENGINEERING

Industrial Relationship. Co-ordinating Engineering With Other Company Activities, L. E. Jermy. Machine Design, vol. 3, no. 6, June 1931, pp. 27–29. Procedure followed by eight companies using committees and conferences to broaden scope of activities of engineering departments.

ENGINEERING EDUCATION

Economics. Die Wirtschaftswissenschaften an den deutschen Technischen Hochschulen-"Der Wirtschafts-Ingenieur" (Economic Sciences at German Technical Universities), F. Froelich. Maschinenbau, vol. 10, no. 10, May 21, 1931, (supp.) pp. W106–W110. Critical discussion of book by W. Prion entitled Der Wirtschafts-Ingenieur (The Industrial Engineer); desirability of engineer with commercial training, rather than vice versa.

Review. Education for the Engineering Industry. Nature (Lond.), vol. 127, no. 3215, June 13, 1931, pp. 881–886. Review of report of committee appointed by President of Board of Education to inquire into technical education for engineering industry.

ENGINEERING LABORATORIES

Germany. Die Hannoversche Versuchsanstalt fuer Grundbau und Wasserbau (The Hanover Experimental Institute for Foundation and Hydraulic Engineering), O. Franzius. V.D.I. Zeit., vol. 75, no. 24, June 13, 1931, pp. 741–745, 10 figs. Discussion of experimental methods used in foundation and hydraulic studies; description of experimental hydraulic and foundation laboratories of Hanover Institute of Technology; results of principal experiments completed; apparatus for testing physical condition of soil; studies of river models; outline of research program.

F

FANS

Propeller. The Aeroto Two-Stage Forced-Draught Fan. Engineering, vol. 131, no. 3413, June 12, 1931, pp. 756–758, 13 figs. partly on p. 766. Propeller type of fan in which high efficiency can be obtained under working conditions developed under patents of M. T. Adamtchik and G. G. Massera, manufactured at their Slough works by British Aerotechnical Co.; test was carried out on S. S. Rodney Star by members of National Physical Laboratory while vessel was steaming down Thames, and results are given.

FEEDWATER TREATMENT

On Shipboard. Some Effects of Impurities in Feed-Water, C. C. Pounder. Mech. World, vol. 89, no. 2319, June 12, 1931, pp. 558–561, 2 figs. Miscellaneous points chiefly arising out of difficulties encountered in writer's experience on shipboard; precautions against oil and against impurities.

Phosphate Deposits. Phosphate Deposits Eliminated by Quick Feed, A. B. Stickney. Power, vol. 73, no. 24, June 16, 1931, p. 947. At Anheuser-Busch power plant phosphates solved problem of boiler cleaning but caused deposits in feed lines and heaters; trouble eliminated by feeding phosphate very rapidly at intervals of one hour or more.

Raw Water. Die Schaeden einer mangelhaften Wasserreinigung in Dampfanlagen (Damages Due to Inadequate Water Purification in Steam Plants), V.D.I. Belani. Petroleum, vol. 27, no. 25, June 17, 1931, pp. 469–474, 5 figs. Example of considerably increased fuel consumption due to use of raw water as boiler feed; design of automatic water-treatment plant made by firm of L. & C. Steinmueller in Gummersbach, consisting of water distributor, preheater, lime saturator, tank for soda solution, and clarification tank.

FITS

Standardization. Standardizing Cylindrical Fits to Simplify Design, J. Gaillard. Machine Design, vol. 3, no. 6, June 1931, pp. 45–47 and 66, 5 figs. Preference of unilateral over bilateral tolerances in general standard system of cylindrical fits; factors involved in requirements.

FLOW OF FLUIDS

Measurement. Durchflussmessung mit genormten Duesen und Blenden (Flow Measurement With Standard Nozzles and Diaphragms), G Ruppel. Archiv fuer Waermewirtschaft, vol. 12, no. 6, June 1931, pp. 173–174. New German regulations of fluid meter committee of Verein deutscher Ingenieure; rules apply to measurement of all liquids, gases, and vapors.

Theory. Some Problems Connected With Fluid Motion, J. J. Green. Eng. Jl., vol. 14, no. 6, June 1931, pp. 351–357, 10 figs. Development of theory of fluid flow; important results following from Prandtl's hypothesis postulating existence of thin layer of fluid close to body in which frictional force between adjacent fluid layers is proportional to velocity gradient normal to direction of motion; result of addition of viscous term by Stokes and then of Prandtl's modification for boundary layer. Before Eng. Inst. Can.

FLOW OF GASES

Measurement. The Measurement of a Rapidly Fluctuating Flow of Gas, J. G. King and B. H. Williams. Engineering, vol. 131, no. 3413, June 12, 1931, pp. 759–760, 6 figs. In making water gas, process of generation is interrupted at short intervals, between which flow of gas is subject to rapid fluctuations; in investigations at Fuel Research Station, it was found necessary to obtain records of total volume flowing through main in given time, and of instantaneous rate of flow at any moment; apparatus used and results obtained during its calibration. From Dept. Sci. and Indus. Research, Fuel Research—Tech. Paper, no. 27. Price 6d. net.

FLOW OF LIQUIDS

Measurement. Determination of Rate of Flow of Liquid by the Levin Method, J. M. Rubinstein. Izvestiya Teplotechnicheskovo Instituta, no. 6–7, 1930, pp. 9–24, 20 figs. Theory of method developed by A. M. Levin in paper published in Transactions of American Society of Mechanical Engineers, vol. 36, 1914, pp. 237–254, based on determination of difference in pressures, on outer and inner sides of pipe bend; results of checking experiments performed in Germany and Russia. (In Russian.)

FORGE SHOPS

Materials Handling. See MATERIALS HANDLING, Forge Shops.

FOUNDRY PRACTICE

Developments. Some Developments in Modern Foundry Practice, E. Longden. Mech. World, vol. 89, nos. 2317 and 2319, May 29, 1931, pp. 517–519, and June 12, pp. 565–567, 7 figs. Paper before Manchester Assn. Engrs., previously indexed from Foundry Trade Jl., Apr. 9 and 16, 1931.

FURNACES

Wood Waste. Furnaces for Waste Fuels, O. de Lorenzi. South. Power Jl., vol. 49, no. 5, May 1931, pp. 40–44, 5 figs. Many waste products of industrial processes are now used as fuel due to development of combustion methods and furnace design; combustion procedure and furnace design of wood waste boilers; features of Dutch-oven; pre-heating of air.

G

GAGES

Chromium Plating. Eighty-Five Thousand Chromium-Plated Gages Used in One Plant—Why? C. O. Herb. Machy. (N. Y.), vol. 37, no. 11, July 1931, pp. 817–820, 3 figs. Advantages of chromium-plated gages determined by extensive laboratory tests at Ford Motor Co.; in certain grinding operations they could be used 218 hours as against 4 hours for tool-steel gages; method of manufacture.

GASES

Purification. The Girdler Process for Gas Purification, R. R. Bottoms. Gas Age-Rec., vol. 67, no. 24, June 13, 1931, pp. 909–913, 7 figs. Principal impurities in industrial gases are carbon dioxide and hydrogen sulphide; five standard scrubbing methods for removal of carbon dioxide; essential characteristics of compound for continuous separation of hydrogen sulphide and carbon dioxide; compounds tested and found suitable; physical properties of ethanolamine, affecting application in gas purification; life of ethanolamine solutions; action of various substances on ethanolamines. Before Am. Gas Assn.

GEARS

Disadvantage of 20 Deg. Die Einfuehrung der 20 Deg. Verzahnung Nach DIN 867 in Die Praxis (Introduction Interpractice of 20 Deg. Toothing According to DIN 867), F. Olah. Werkstattstechnik, vol. 25, no. 10, May 15, 1931, pp. 249–253, 3 figs. Presumable disadvantages of 20 deg. toothing; great axial pressure, higher susceptibility to vibration; experimental data pertaining to susceptibility to vibration for different contact angle and various profile corrections; advantages are higher load capacity of teeth and uniformity of tooth shape.

Involute. Graphische Rechentafel (Nomogramm) und Naeherungsformel fuer die Berechnung der Eingriffsminderung durch die Zahnunterschneidung bei Evolventensatzraedern (Graphic Chart and Approximate Formula for Calculating Reduction of Working Depth by Tooth Undercutting for Involute Gears), A. Fischer. Zeit. des Oesterreichischen Ingenieur. und Architekten Vereines, vol. 83, no. 17–18, May 1, 1931, pp. 151–152, 2 figs.

Worm. Pitting in Worm Gears, H. Walker. Automobile Engr., vol. 21, no. 281, June 1931, pp. 223–224, 8 figs. Consideration of factors causing pitting in service; elimination of secondary contact in Holroyd worm thread for automobile rear axles.

GLIDERS

Design. Segelflug-Wettbewerb 1929 in der UdSSR. (During Competition in 1929 in USSR), Stoklitzky. Zeit. fuer Flugtechnik und Motorluftschiffahrt, vol. 22, no. 11, June 15, 1931, pp. 335–336, 8 figs. Design of representative types and tables of principal dimensions; comparison of German and Russian results.

GLIDING

Conditions for. The Meteorological Aspects of Gliding and Soaring Flight, F. Entwistle. Roy. Aeronautical Soc.—Jl., vol. 35, no. 246, June 1931, pp. 423–449 and (discussion) 449–459, 26 figs. Conditions for gliding and soaring flight; wind structure; principal types of recording instruments; magnitudes and extent of vertical currents; applications to gliding and soaring flight. Bibliography.

Eleventh Rhoen Soaring-Flight Contest, 1930, W. Georgii. Nat. Advisory Committee for Aeronautics—Tech. Memo., no. 623, June 1931, 16 pp., 9 figs. Interpretation of weather conditions for principal endurance, altitude and long-distance flight with tables and maps. Translation of paper previously indexed from Zeit. fuer Flugtechnik und Motorluftschiffahrt, Mar. 14, 1931.

GRINDING

Form. Form Grinding in Successive Operations, W. C. Betz. Am. Mach., vol. 74, no. 24, June 11, 1931, pp. 901–902, 5 figs. Form grinding tool for automatic screw machine, using three separate wheels; radial wheel truing fixture for both concave and convex radii; truing fixture for bevel surfaces, used on centers, or platen, or either side up; examples of form grinding with several wheels.

H

HARDNESS

Testing Machines. Modern Testing of Hardness, H. Percival. West. Machy. World vol. 22, no. 6, June 1931, pp. 247–249, 3 figs. Mohs scale, in which 10 representative minerals are selected as representing 10 successive degrees of hardness, to which hardness numbers running from 1 to 10 are assigned; scratch test; measurement of indentation; pendulum test; method of Shore scleroscope; Monotron hardness testing machine.

HELICOPTERS

Design. Note sull'elicottero ed i suoi recenti sisultati (Notes on Helicopters and Recent Results), A. Fiore. L'Ingegnere, vol. 5, no. 3, Mar. 1931, pp. 169–173, 3 figs. Summary of problems in helicopter design and their solution by Anscanio type; performance data.

HYDRAULIC TURBINES

Design. The Development of the Francis Turbine With Special Reference to the Recent Researches Made by Escher Wyss and Co., J. Moser and E. Seitz. Escher Wyss News, vol. 3, no. 4, Oct.-Dec. 1930, pp. 147-158, 24 figs.

HYDROELECTRIC POWER DEVELOPMENTS

Switzerland. Water-Power Developments in Switzerland. World Power, vol. 15, no. 89, May 1931, pp. 377-378. Management of internal watercourses; regulation of seasonal variation in water supplies; lake storage of water; hydroelectric economy; export of energy from Switzerland to neighboring countries; description of Riedgi automatic station operated from Achersand Station, two plants being connected by 15,000-volt transmission line.

HYDROELECTRIC POWER PLANTS

Automatic. Des centrales automatiques à plusieurs groupes et des turbines à plusieurs distributeurs (Multiple Unit Automatic Power Plants and Multiple Turbine), F. Salgat. Schweizerische Bauzeitung, vol. 97, nos. 17 and 18, Apr. 25, 1931, pp. 211-215, and May 2, pp. 223-225, 14 figs. Determination of most efficient automatic regulation method under all load conditions, which allows for parallel operation with suitable load on all turbines in service; plant with two hydraulic turbines of 315 and 733 hp. at 55.55 m. head at Tréfileries Reunis de Bienne.

Manitoba. Winnipeg Electric Company's Seven Sisters Development, F. H. Martin. Elec. News, vol. 40, no. 12, June 15, 1931, pp. 108-114, 6 figs. Plant has total installed capacity of 225,000 hp. under operating head of 66 ft.; three different types of turbine settings installed in initial development; cross-sectional drawings and illustrations of plant nearing completion; simple line diagram of connections.

The City of Winnipeg's New Slave Falls Development. Elec. News, vol. 40, no. 12, June 15, 1931, pp. 103-104, 3 figs. Ultimate development will consist of eight 12,000-hp. units operating under normal head of 30 ft.; two units have been installed in initial development; site is situated approximately six mi. south of Pointe du Bois; length of powerhouse structure will be 530 ft.; west dam contains four large sluice gates 50 ft. wide which, with aid of spillway, will be capable of discharging flood waters exceeding 100,000 cu. ft. per sec.

Ontario. Alexander Power Development on the Nipigon River, T. H. Hogg. Hydro-Elec. Power Commission Ont.—Bul., vol. 18, no. 5, May 1931, pp. 161-172, 10 figs. Paper before Eng. Inst. Can., previously indexed from various sources.

Remote Control. Automatic and Remotely Controlled Hydro-Power Plant. AEG Progress, vol. 7, no. 5-6, May-June 1931, pp. 99-106, 8 figs. Review of automatic and remotely controlled plant on basis of experience accumulated by AEG in construction of numerous automatic hydro-power stations for output totalling well over 100,000 kw; important factors requiring study when planning electrical section of small and medium sized stations.

Saskatchewan. Power Development at Island Falls, Churchill River, M. H. Marshall. Eng. Jl., vol. 14, no. 6, June 1931, pp. 325-330, 12 figs. Churchill River basin and storage conditions; construction of plant; total freight dealt with during construction was 35,000 tons; three main turbine units are installed, of 14,000 hp. at 56-ft. head and 163.6 r.p.m.; three vertical 3-phase, 60-cycle generators of 12,000 kva., develop 6600 volts, which is stepped up to 110,000 kv. for transmission over 58 miles to Flin Flon and 45 mi. branch line to Sherritt-Gordon.

I

IMPACT TESTING

Notched Bar. Kritische Kerbzaehigkeitswerte (Critical Notch-Toughness Values), W. Kuntze. Mitteilungen der deutschen Materialpruefungsanstalten, no. 14, 1930, pp. 44-58, 23 figs. Critical fields of reduction from maximum to minimum values of impact effects render notch-toughness testing difficult; for this reason it is advisable not to confine investigations to single values, but to extend them to series of tests; it is deemed urgent to develop expression of notch toughness as coefficient of quality, and this can be accomplished only by standard test.

INDUSTRIAL MANAGEMENT

Planning Production. Management A B C's—4 Planning Production, H. Diemer. Factory and Indus. Mgmt., vol. 82, no. 1, July 1931, pp. 59-61, 3 figs. Stages in planning production making of general sales estimates and financial budgets on which major plans are based; translation of these general estimates into daily details of manufacturing schedules for plant operation.

Small Plants. Small Plant Successes, A. C. Hough. Factory and Indus. Mgmt., vol. 82, no. 1, July 1931, pp. 47-48. Management methods used by Hough Shade Corp., Janesville, Wis., for manufacture of porch shade of basswood slats, employing 140 factory workers.

INDUSTRIAL PLANTS

Air Conditioning. Predetermining the Aeration of Industrial Buildings, W. C. Randall and E. W. Conover. Heat., Piping and Air Conditioning, vol. 3, no. 6, June 1931, pp. 513-518, 7 figs. Outline of method for determination of building aeration before construction with sufficient accuracy for practical purposes; flow due to temperature difference; flow due to wind; flow due to combined wind and temperature difference; solution of typical problem; summary and conclusions. Before Am. Soc. Heat. and Vent. Engrs.

Purchased vs. Generated Power. The Cost of Operating Industrial and Private Electric Generating Sets Compared With Public Supply, E. G. Phillips. Eng. and Boiler Rev., vol. 44, nos. 10 and 11, Apr. 1931, pp. 677-679, and May, pp. 737-740 and 742-743. Previously indexed from Domestic Eng. (Lond.), Jan. 1931.

INTERNAL-COMBUSTION ENGINES

Carbon Removal. The Use of Carbon-Removing Compound in Internal-Combustion Engines, C. R. D'Olive. Motive Power, vol. 2, no. 6, June 1931, p. 25. Practical review of loss of power due to carbon and gum formations; method of carbon removal by compound injection either through plug ports or intake manifold. Before Am. Soc. Agric. Engrs.

Combustion. Zur Theorie des Verbrennungsraumes (Theory of Combustion Chamber). Automobiltechnische Zeit., vol. 34, nos. 12, 13 and 14, Apr. 30, 1931, pp. 275-278, May 10, pp. 310-312 and May 20, pp. 332-335, 29 figs. Survey of combustion chamber design and method of controlling detonation in different types of combustion chambers based on research work of Ricardo, Whatmough, Janeway, and Taub; flame propagation, roughness, turbulence, rate of pressure rise; effect of offset combustion chamber on 10 thermo-efficiency; application of streamlining to combustion chamber and valve design.

High Speed. High-Speed Internal-Combustion Engine, H. R. Ricardo. Lond. & Glasgow, Blackie & Son, Ltd., 1931, 435 pp., illus., diagrams, charts, tables. Thorough analysis of scientific basis of design, based upon extensive research and experimentation; general principles, rather than specific designs, are discussed. Eng. Soc. Lib., N. Y.

Lubrication. Le remontée d'huile dans les cylindres (Oil Pumping), Lienhard. Société des Ingénieurs de L'Automobile—Jl., vol. 4, no. 4, Apr. 1931, pp. 1346-1350. Analysis of principal factors contributing to oil pumping, and its effects on engine performance; influence of oil in combustion chamber on detonation; reduction of pumping by special rings.

Six-Cycle. Ueber Verbrennungsvorgaenge in Motoren und das Sechstaktprinzip (Combustion Phenomena in Internal Combustion Engines and Six-Stroke Cycle), E. Terres. Zeit. fure angewandte Chemie, vol. 44, no. 24, June 13, 1931, 509-519, 27 figs. Author is working on new principle called 6-stroke cycle; process is performed in two cycles of action during three revolutions in six operations, namely, absorption of fuel mixture; compression and ignition; incomplete combustion and expansion; compression and admixture of compressed secondary air; secondary combustion and expansion; and pressing out of combustion gases; 17 per cent of fuel energy is converted into mechanical energy.

Vibrations. Bestimmung der Drehschwingungszahlen von Motorenanlagen (Determination of Torsional Vibration Periods of Engine Insulation), H. Behrens. Automobiltechnische Zeit., vol. 34, no. 16, June 10, 1931, pp. 376-378, 6 figs. Graphical method for direct determination of torsional vibration period of engine with one or two rotating masses; period of engine with two masses can be determined satisfactorily by approximating method.

[See also AIRPLANE ENGINES; DIESEL ENGINES.]

IRON AND STEEL

Corrosion. Recent Developments in Corrosion Prevention of Ferrous Metals, V. V. Kendall and F. N. Speller. Indus. and Eng. Chem., vol. 23, no. 7, July 1931, pp. 735-742, 11 figs. Review covers atmospheric corrosion; methods of testing corrosion; underwater corrosion; reconditioning of water pipes and water-cooling apparatus; boiler problems; soil corrosion; corrosion in oil industry. Bibliography. Before West. Metal Congress.

Corrosion of Iron and Steel. Iron and Coal Trades Rev., vol. 122, nos. 3299, 3300, 3301 and 3302, May 22, 1931, pp. 834-835, May 29, p. 861, June 5, p. 900 and June 12, p. 942. May 22: Extracts from Section B of first report of Corrosion Committee of Iron and Steel Institute, statistical résumé of replies received to questionnaire; replies are grouped. May 29: Replies from railway companies. June 5: From shipping companies. June 12: From engineering firms; from iron and steel manufacturers and associated companies.

IRON FOUNDRY

Practice. Compte Rendu du Congrés International de Fonderie de Liége 23-28 Juin 1930 (International Foundry Congress at Liége, June 23-28, 1930), Renaud. Revue de Métallurgie, vol. 28, no. 5, May 1931, pp. 268-288, 11 figs. Review of papers read: Manufacture of Steel Castings, J. Deschamps; Light Metals in Italy, A. W. Bonaretti; Melting Furnaces in Iron Foundries, T. Geilekischen; Pulverized Coal in German Malleable Foundries, Stotz; Air Pressure and Volume in Cupolas, Canameras and Gonzalo; Papers on Foundry Testing, H. Thyssen, A. Deleuze, F. Pisek, and J. Bourdouxhe; Molding Sand, A. Deleuze; Electrolytic Iron, R. B. Dupeis; etc.

L

LOCOMOTIVES

Baltimore and Ohio. New Baltimore and Ohio Locomotives Designed to Suit the Railroad, W. A. Austin. Baldwin Locomotives, vol. 10, no. 1, July 1931, pp. 39-46, 8 figs. Description of two mountain and two articulated type locomotives recently built by Baldwin Works for Baltimore and Ohio Locomotive Co.; tabular review of weights and dimensions.

Design. Ueber die rechnerische Vorausbestimmung der guenstigsten Fahrgeschwindigkeit von Kolbenheissdampflokomotiven einstufiger Dampfdehnung (Numerical Predetermination of Favorable Traveling Speed of Reciprocating Superheater Steam Locomotives of Single Expansion Type; T. Achterberg. Glasers Annalen, vol. 108, no. 11, June 1, 1931, pp. 171-174, 4 figs. Influence of admittance temperature, comparison between twin, triple and quadruple locomotives; results, shortcomings, and features of method.

On the Calculation of the Draw-Bar Pull of Steam Locomotives—III, R. Nakamura. Japanese Govt. Railways—Bul., vol. 19, no. 19, May 10, 1931, 12 pp., 6 figs. As result of tests on steam locomotives in Oi locomotive testing plant, formula has proved recommendable for maximum available tractive force at low speed. (Brief English abstract.)

Diesel. Diesel Locomotive Design—IV, J. Geiger. Ry. Engr., vol. 52, no. 617, June 1931, pp. 235-240, 2 figs. Economic considerations involved in Diesel locomotive design; fuel consumption of steam and Diesel locomotives; cost comparisons for various countries; wages cost of locomotive personnel; costs of shop repairs; interest and redemption charges on auxiliary equipment; miscellaneous costs.

A New Disel Locomotive Development. Petroleum Times, vol. 25, no. 646, May 30, 1931, pp. 791-792, 4 figs. Design, construction and operating features of engine built by Swiss Locomotive and Machine Works, Winterthur, on Swiss Federal Postal Department for freight and shunting service; coupled wheels 2 ft. $9^1/_2$ in.; wheelbase 9 ft. $2^1/_4$ in., 6-cylinder, single-acting, 4-stroke, with airless injection developing 150 hp. at 850 r.p.m.; fuel consumption not over 0.4 lb. per hp-hr.

High Pressure. 2-10-4 Type Locomotive With Schmidt Boiler for the Canadian Pacific Railway. Engineering, vol. 131, no. 3413, June 12, 1931, p. 780, 1 fig. First multi-pressure boiler locomotive on American continent is three-cylinder compound with one high-pressure inside cylinder $15^1/_2$ in. in diam. by 28-in. stroke, and two outside low-pressure cylinders 24 in. in diam. by 30-in. stroke.

Die 60 at Hochdruck-Locomotive, Winterthur (60 Atmosphere High-Pressure Locomotives, Winterthur), H. Nyffdnegger. Schweizerische Bauzeitung, vol. 97, no. 24, June 13, 1931, pp. 297-298, 6 figs. Design and performance data of locomotive developing 805 hp. at 60 km. per

hr. corresponding to cylinder output of approximately 950 indicated hp.

Roller Bearings. Experimental Locomotive Fitted With Roller Bearings. Ry. Engr., vol. 52, no. 617, June 1931, pp. 229–232, 5 figs. Timken Roller Bearing Company received 4-8-4 type locomotive from American Locomotive Company; engine constructed to demonstrate utility of roller bearings in locomotive construction; adhesion weight can be varied in accordance with higher or lower steam pressure in boiler; cylinders 27 by 30 in.; coupled wheels 6 ft. 1 in.; total engine wheel base 45 ft. 10 in.; steam pressures, 235 and 250 lb. per sq. in.; total engine and tender weight in working order 317.6 tons; maximum starting tractive force 71,900 lb.; axle and bearing details.

LUBRICATING OIL

Solvent Extraction. Solvent Extraction of Lubricating Oils, S. W. Ferris, E. R. Birkhimer, and L. M. Henderson. Indus. and Eng. Chem., vol. 23, no. 7, July 1931, pp. 753–761, 12 figs. Preliminary tests on 110 substances as possible selective solvents; 21 subjected to exhaustive tests on separation of three different stocks; results are critically examined, using viscosity-gravity constant of respective fractions as index of degree of separation. Bibliography. Before Am. Chem. Soc.

Steam Turbines. Some Notes on Turbine Circulation Oils, G. B. Godwin. S. African Instn. Engrs.—Jl., vol. 29, no. 9, Apr. 1931, pp. 189–201, 3 figs. Comparison of physical and chemical properties of fixed oils and fats and mineral oils; indication of deterioration; derivation of water in lubricating system.

M

MACHINE TOOLS

Design. Les tendance récentes dans la technique des Machines-outils (Recent Trends in Design of Machine Tools), A. Lambette. Pratique des Industries Mécaniques, vol. 14, no. 3, June 1931, pp. 95–106, 32 figs. General tendencies; sawing machines, presses, grinding machines; center, turret, and automatic lathes; milling machines, planing machines, etc.

Zur Frage der Sicherheit in der Konstruktionslehre (The Problem of Safety and the Theory of Design), A. Thum. V.D.I. Zeit., vol. 75, no. 23, June 6, 1931, pp. 705–708, 6 figs. Danger of failure due to static stresses is generally overrated while danger of failure due to vibration stresses is generally underrated; critique of modern methods of design, particularly with regard to notched section effects in various construction materials; urgent problems in materials research.

Stresses in Fillets, E. F. Garner. Product Eng., vol. 2, no. 6, June 1931, pp. 259–261, 5 figs. Calculation of concentrated stresses; stress-concentration factors for tension, compression or transverse stress corresponding to values of ratio of depth or radii of connected members and ratio of fillet radius to radius of smaller section; variation of stress concentration with change in ratio of fillet radius to radius or depth of smaller member and average variation of stress concentration with variation in ratio of depth of connected members, for tension, compression, or transverse stress.

Hydraulic Drive. Machine Tool Operation—Use of Hydraulic Power. Times Trade and Eng. Supp., vol. 28, no. 675, June 13, 1931, p. 290. Advantages to be gained by adoption of oil-driven motions; applications; operating systems; rotary motor drives; auxiliary functions.

MATERIALS HANDLING

In Coke Plants. Reducing Coke and Gas Coal Breakage, E. J. Tournier. Gas Age-Rec., vol. 67, no. 18, May 2, 1931, pp. 667–669, 6 figs. Principal causes of breaking of fuel are lowering into bins, drawing out of bins, and loading into railroad cars or trucks; features of special types of chute to facilitate lowering coal and coke into and out of storage bins.

Modern. They Licked the Problem of Waste by Modern Handling, J. A. Cronin. Matls. Handling and Distribution, vol. 6, no. 3, June 1931, pp. 19–23, 19 figs. Entire renovation of plant of Transue-Williams Steel Forging Corp., Alliance, Ohio, based on planned system of materials handling.

Successful. When Does Mechanical Handling Pay? M. G. Farrell. Mill and Factory Illustrated, vol. 8, no. 6, June 1931, pp. 37–39, 84 and 85, 2 figs. Cases in which mechanical handling has been applied successfully to industries in which it had never been used before.

METALS

Cold Working. Tammanns Untersuchungen ueber Kaltreckung, Verfestigung und Rekristallisation (Tammann's Studies of Cold Working, Strengthening and Recrystallization), G. Masing, Zeit. fuer Metallkunde, vol. 23, no. 5, May 1931, pp. 139–142, 2 figs. Investigation of plastic deformation; strengthening by cold working; recrystallization; displacement of crystallite boundary; lattice orientation.

Corrosion. Korrosion von Metallen unter der Einwirkung von verschiedenen fluessigen Brennstoffen (Corrosion of Metals Under Influence of Various Liquid Fuels). Automobiltechnische Zeit., vol. 34, no. 16, June 10, 1931, pp. 384–385. Report on experiments by S. Uspenski and Ladyshnikow, of Moscow Petroleum Research Institute; data on gasoline, benzine, various types of alcohol, and of acetone.

The Relation of the Moisture in Rust to the Critical Corrosion Humidity, W. S. Patteson and L. Hebbs. Faraday Soc.—Trans., vol. 27, pt. 6, June 1931, pp. 277–283, 2 figs. Results of tests.

Begruessungsansprache und Bericht ueber Korrosionsarbeiten des "Reichsausschusses fuer Metallschutz" (Report of Corrosion Research of German Government Committee on Protection of Metals), E. Maass. Korrosion und Metallschutz, vol. 7, no. 5, May 1931, pp. 97–104, 7 figs. Activities of Committee; results of research and experiments.

Cutting. Das Senken und Reiben von Bohrungen in Eisen und Nichteisen-Metallen (Reaming of Holes in Ferrous and Nonferrous Materials), A. Wallichs and H. Schalbroch. Werkstattstechnik, vol. 25, no. 11, June 1931, pp. 273–280, 18 figs. Report of Machine Tool Laboratory of Technical University of Aachen; cutting forces influenced by diameter, cutting depth, feed, cooling medium and shape of tool; measuring methods for properties of various test materials including cast iron, steels, drafts, bronze, and aluminum alloys.

Fatigue Testing. Untersuchung metallischer Baustoffe auf Schwingungsfestigkeit mit der Hochfrequenz - Zug - Druck - Maschin (Bauuart Schenck), (Study of Vibration Strength of Metallic Building Materials With Aid of High Frequency Tension-Compression Machine of Schenck Design), K. Memmler and K. Laute. Mitteilungen der deutschen Materialpruefungsanstalten, no. 15, 1931, pp. 39–70, 60 figs. Detailed description of mechanical and electrical parts of Schenck fatigue testing machine; operating experience with machine; results of tests of specimens of carbon, silicon, and chromium-nickel steels, also nickel, brass, elektron, and other alloys.

Low Temperatures. Endurance and Other Properties at Low Temperatures of Some Alloys for Aircraft Use, H. W. Russell and W. A. Welcker, Jr. Nat. Advisory Committee for Aeronautics—Tech. Notes, no. 381, June 1931, 16 pp., 20 figs. Design of apparatus for testing endurance at minus 40 deg. cent.; test results for monel metal, low-carbon stainless steel, "18 and 8," 3½ per cent Ni steel and chromium-molybdenum steel at 40 deg. cent. and at room temperature (about 20 deg. cent.); results show increase in endurance limit, tensile strength, and hardness with decreased temperature.

Non-Ferrous. The Use of Compressed-Air Pressure Plates for Non-Ferrous Metal Working, O. Kuehner. Metal Industry (Lond.), vol. 38, no. 22, May 29, 1931, pp. 545–547, 7 figs. With aid of devices described important advantages are obtained in drawing of non-ferrous metals, especially thin strip, chiefly owing to possibility of utilizing to full, drawing capacity of material; economy of drawing process is raised considerably by saving in annealing operations, by fact that sorting of strip is no longer necessary, and by reduction in setting-up time. Translated from German.

Beitrag zur Erkenntnis der elastischen Eigenschaften der Leichtmetalle (Contribution to Knowledge of Elastic Properties of Light Metals), H. Sieglerschmidt. Mitteilungen der deutschen Materialpruefungsanstalten, no. 14, 1930, pp. 40–44, 6 figs. Longitudinal expansion and transverse contraction measurements were made on round bars of duralumin, lautal and elektron metal for determination of stress distribution in girders.

Temperature Effect. Joint Research Committee on Effect of Temperature on the Properties of Metals. Am. Soc. Testing Matls.—Advance Paper, no. 29, for mtg. June 22–26, 1931, 19 pp., 15 figs. Progress report to sponsor societies; Progress Report on Fatigue Tests of Low-Carbon Steel at Elevated Temperatures, H. F. Moore and N. J. Alleman; Apparatus for Low-Temperature Endurance Testing, H. W. Russell and W. A. Weicker, Jr.

Testing. Die Bruchgefahr bei metallischen Werkstoffen (Danger of Fracture in Metallic Materials), W. Kuntze. Mitteilungen der deutschen Materialpruefungsanstalten, no. 14, 1930, pp. 60–71, 17 figs. It is claimed that, as direct application of laws of atomic physics to strength of crystalline metals has not yet been successful, technological solution of strength problems, as practiced in government and private industrial research laboratories, is necessary.

X-Ray Analysis. Die Ursachen der Linienverbreiterung bei Pulver- und Drehkristallaufnahmen mit Roentgenstrahlen (Causes of Curve Widening of Monochromatic X-Ray Photographs of Crystals), Y. Dehlinger. Zeit. fuer Metallkunde, vol. 23, no. 5, May 1931, pp. 147–149, 7 figs. Three causes of curve broadening are possible: slow fluctuations in lattice, abnormally small grains, and rapid fluctuations of lattice.

O

ORIFICES

Discharge. Die Eurchflusszahlen von Normblenden mit und ohne Stoerung des Zuflusses (Discharge Coefficients of Standard Diaphragm Orifices for Disturbed and Undisturbed Flow), G. Ruppel and H. Jordan. Forschung auf dem Gebiete des Ingenieurwesens, vol. 2, no. 6, Ausgabe B, June 1931, pp. 207–212, 11 figs. Discussion of fundamental equation and of experimental results obtained by Witte in Germany and by United States Bureau of Standards; report on further German experiments which show that errors of measurement decrease with increase in velocity, also that orifices of small dimensions are insensitive to disturbances in flow.

P

PETROLEUM

Africa. Petroleum Development in Africa, W. B. Heroy. Petroleum Times, vol. 25, no. 636, Mar. 21, 1931, p. 406. Egypt is only producer of importance on African Continent; production is derived from Gemsah and Hurghada fields, on west coast of Red Sea, and Abu Durba, on eastern shore in Sinai peninsula; production statistics; notes on petroleum prospecting in Somaliland, Mozambique, Angola, Morocco, and Algiers. Before Am. Inst. Min. and Met. Engrs.

Refining. The Fractionation of Light Distillates, H. P. Rue and R. H. Espach. Petroleum Times, vol. 25, no. 639. Apr. 11, 1931, p. 530. Previously indexed from various sources.

Refining by Continuous Counter-Current Treatment. Petroleum Times, vol. 25, no. 637, Mar. 28, 1931, pp. 441–443, 4 figs. New methods developed by Anglo-Persian Oil Co., Ltd.; flow sheet diagram of testing plant; method has been applied to treatment of straight-run and cracked motor gasoline and all other distillates up to and including heavy kerosene, when employing alkaline hypochlorite solution, sulphuric acid, or alkali.

Recent Developments in Fractional Distillation, C. H. S. Edmonds. Petroleum Times, vol. 25, nos. 640 and 641, Apr. 18, 1931, pp. 559–560, and Apr. 25, pp. 599–600. Developments in tube still design; primary heating system; developments in fractionating equipment; heat recovery; fractionation; vacuum and two-stage operation; advantages of processing heavier fractions of crude under vacuum. Befor Instn. Petroleum Technologists.

PIPE LINES

Corrosion. Field Measurement of the Corrosiveness of Soils. Am. Gas Jl., vol. 134, no. 4, Apr. 1931, pp. 34–35, 3 figs. Comment on field investigation of U. S. Bureau of Standards, such as reported in U. S. Bur. Standards—Jl. Research, Apr. 1931, previously indexed; notes on Shepherd earth-resistivity meter, conforming to Bureau of Standards design and being distributed by O. S. Peters, Washington, D. C.

Welding. High-Pressure Pipe Lines, J. Kloepper and J. Wasser. Eng. Progress, vol. 12, no. 6, June 1931, pp. 121–127, 17 figs. Water-gas lap-welded pipe in its application of high-pressure gas and water lines; review of salient points of fabrication and properties of welded pipe.

Pipe Welding—How, When and Where to Do It—II, W. Sparagen. Welding, vol. 2, no. 6, June 1931, pp. 389–393, 9 figs. Welding of nozzles; fabricated and notched bends; welded pipe anchors; welding of oil, gas and water pipe lines; templet layout for bull plug.

POWER PLANTS

Design. Modern Power Basic Principles, Design and Application—XIII, F. T. Morse. South. Power Jl., vol. 49, no. 6, June 1931, pp. 41–46, 7 figs. Review of three steam cycles of modern steam power engineering which are Rankine, predominating in industrial plants; regenerative used almost without exception in central station practice; and reheating regenerative cycle which is particularly adapted to high pressures.

United States. American High Pressure Central Electric Stations. Izvestiya Teplotechnicheskovo Instituta, no. 8–9, 1930, pp. 10–89, 79 figs. Report on observations on American power plant practice made by specially commissioned Russian engineer; description of famous power stations; types of high pressure boilers, economizers, pumps; regulation of turbo-generators, etc. (In Russian.)

PRESSURE VESSELS

Electric Welding. Electric Welding Applications to Steam Pressure Vessels. Power Plant Eng., vol. 35, no. 12, June 15, 1931, pp. 667, 4 figs. Electric welding of steam piping and directly fired steam drums has now passed experimental stage of development and during past year and half number of noteworthy applications have been made in power plant field; review of outstanding applications.

PRODUCTION CONTROL

Small Plants. A 24-Hr. Working Shop Borrows a 10,000-Man Plan. Factory and Indus. Mgmt., vol. 82, no. 1, July 1931, pp. 42–43, 4 figs. Production-control methods of Hammond Machine Builders, Kalamazoo, Mich., in manufacture of printers' saws, polishing and buffing lathes, automatic polishing and grinding machinery, sawmill machinery, electric grinders, and electric knife sharpeners.

PROTECTIVE COATINGS

Metallic. Seewasserbestaendigkeit galvanischer Ueberzuege auf Eisen und Leichtmetallen (Seawater Resistance of Galvanic Coatings on Iron and Light Metals), K. O. Schmidt. Korrosion und Metallschutz, vol. 7, no. 5, May 1931, pp. 111–112, 3 figs. Previously indexed from Zeit. fuer Flugtechnik und Motorluftschiffahrt, Mar. 14, 1931.

PUMPS

Centrifugal. On Potential Flow of Water Through a Centrifugal Impeller, S. Uchimaru and S. Kito. Tokyo Imperial Univ.—Faculty of Eng.—Jl., vol. 19, no. 8, May 1931, pp. 191–223, 22 figs. Formulas for flow from single discharge source, around origin, from vortex source; form of vane curve adopted; motion of water at center of impeller.

The Axial-Radial Pump, W. S. Frankenthal. Eng. Progress, vol. 12, no. 6, June 1931, pp. 129–132, 10 figs. Design characteristics and hydraulic properties; compact form renders this pump type preeminently fit for drainage and deep-well use; economic advantages.

Impeller. Full-way "Mopump." Engineer, vol. 151, no. 936, June 19, 1931, p. 690, 2 figs. For use in forced-circulation heating systems Rhodes, Brydon and Youatt, Ltd., have designed pump of impeller type which offers when at rest less resistance to flow of liquid than non-return valves of corresponding aperture; impeller is so proportioned that full bore of passages of pump body is continued through it; driven by vertical a.c. motor.

R

RIVETS

Design. On Solid Rivets, M. Langley. Flight, vol. 23, no. 22, May 29, 1931, pp. 478d–478h, 14 figs. Design and relative strength of rivets and riveted joints with formulas and data for aluminum alloys and steel, and different plate thicknesses; stresses and spacing of rivets; precautions and workshop practice.

ROLLING MILLS

Electric Drive. Twin Motor Drive. R. H. Wright and H. E. Stokes. Iron and Steel Engr., vol. 8, no. 6, June 1931, pp. 246–250, 5 figs. Form of rolling-mill drive in which one of pair of rolls is independently driven by separate motor; in true twin-motor drive motors may not operate at exactly same speed at all times nor do they depend entirely on coupling effect of metal being rolled to maintain correct load division and speed-relations; electrical and mechanical characteristics of system.

S

SCREW THREADS

Special. Change-Gears for Cutting Special Threads, F. E. Averill. Machy. (N. Y.), vol. 37, no. 11, July 1931, pp. 844–847, 3 figs. A method of utilizing various settings of change-gear box to avoid using special auxiliary gears; calculating auxiliary change gears for cutting pitches not within rage of regular gearbox.

Strength. Zur Festigkeit im Schraubengewinde (Strength of Screw Threads), W. Kuntze. Mitteilungen der deutschen Materialpruefungsanstalten, no. 14, 1930, pp. 35–38, 2 figs. Examples given show that notching may bring advantages with regard to strength; greater breaking resistance in notch cross-section; influence of different refining processes; significance of shearing stress.

SEAPLANES

Float Testing. Der neue Schleppkanal fuer hohe Geschwindigkeiten der Hamburgischen Schiffbau-Versuchsanstalt (New Tank for High Speeds of Hamburg Shipbuilding Research Institute), G. Kempf and W. Sottorf. Werft Reederei Hafen, vol. 12, no. 11, June 1931, pp. 175–180, 12 figs.; see also Mar. Eng. and Motorship Bldr., vol. 54, no. 646, July 1931, p. 276. Tank 322 m. long, 5 m. wide and 2.5 m. deep, is to be devoted solely to seaplane work; dynamometer truck is built up of welded steel tubes, and whole truck is cleaded round with thin streamline body.

Landing. Ueber den Landestoss von Seeflugzeugen (Landing Impact of Seaplanes), W. Pabst. Zeit. fuer Flugtechnik und Motorluftschiffahrt, vol. 22, no. 1, Jan. 14, 1931, pp. 13–28, 27 figs.; see also Nat. Advisory Committee for Aeronautics—Tech. Memo., no. 624, June 1931, 29 pp., 28 figs. Synopsis of landing-impact theory; tests, procedure and equipment of D.V.L.; force measurements on float gear of "HE 9a" with flat-bottom and with V-bottom floats; stress measurements on float gear struts, bottom-pressure measurements on "HE 5" float and deflection measurements on bottom of flying boat; inertia coefficients for development of landing-impact safety factors.

SHAFTS

Vibrations. Sul calcolo dei periodi di oscillazione torsionale libera degli alberi (Calculation of Period of Free Torsional Vibration of Shafts), A. Capetti. Aerotecnica, vol. 11, no. 2, Feb. 1931, pp. 157–166, 6 figs. Methods of determining natural frequencies with particular regard to graphical methods, developed according to Kutzbach.

SHERARDIZING

Rust Proof. The Spray-Sherardizing Rust-Proofing Process. Engineering, vol. 131, no. 3412, June 5, 1931, p. 750, 1 fig. History of dry-vapor galvanizing or sherardizing process; new development known as spray sherardizing or spray-rustproofing, consists in spraying zinc dust, similar to that employed in older processes, on structural-steel surfaces after erection is complete; stated to be suitable for coating bridges, buildings, roofs, ships, tanks, and other similar structures.

SMOKE ABATEMENT

International Contest. Le concours de dépoussierage des fumees industrielles à l'exposition internationale de Liege (Industrial Smoke-Abatement Contest at International Exposition of Liége), V. Firket. Revue Universelle des Mines, vol. 5, no. 12, June 15, 1931, pp. 325–333, and vol. 6, no. 1, July 1, pp. 7–16, 15 figs. June 15: Reasons for organization of International Contest which took place in 1930; exhibits of dust-removal and collecting equipment; building erected by executive committee; dust-collecting installations; testing equipment. July 1: Dust analysis; types of dust collectors.

Industrial. Industrial Smoke Abatement, B. Frisby. Eng. and Boiler House Rev., vol. 45, no. 1, July 1931, pp. 66–67. Points on overloaded boilers, fuel economy, selection of coal, insulation, etc.

Studies. Smoke and Its Prevention, H. M. Faust. Ohio State Univ. Studies—Eng. Experiment Station—Cir. no. 24, June 1931, 15 pp., 8 figs. It is suggested that various coals available in any particular locality be tried, according to recommended methods of firing, under operating conditions of equipment where they are to be used to determine which fuel is most satisfactory in producing heat at lowest cost; cause of smoke; cost and cure.

Value. Smoke Eradication to Save the Health Value of Urban Sunshine, F. O. Tonney and C. R. DeYoung. Heat. and Vent., vol. 28, no. 6, June 1931, pp. 60–63, 5 figs. Paper previously indexed from Am. Jl. Pub. Health, Apr. 1931.

SPRINGS

Helical. Shear Stresses in Helical Springs, L. B. Adams. Engineer, vol. 151, no. 3937, June 26, 1931, pp. 698–699, 2 figs. Theory developed is based on what writer has called "Roever Effect," after A. Roever, who in 1913 was perhaps first to realize that stress distribution in spring, due to pure torsion, was not directly proportional to distance of spring fiber from geometric center of section of wire; theoretical results are in very close agreement with careful experimental work of Special Research Committee on Springs of The American Society of Mechanical Engineers.

STEAM ELECTRIC POWER PLANTS

High Pressure. L'evolution des centrales thermiques et les progrès réalisables par l'emploi de la vapeur à haute pression (Development of Steam Electric Power Plants and Possible Progress From Use of High Pressure Steam), R. Koch and P. Rothfelder. Revue d'Electricité et de Mécanique, no. 16, Mar.-Apr. 1931, pp. 8-XVI-XVI-15, 7 figs. Influence of characteristics of admission steam of turbine on thermodynamical and thermal efficiency; choice of steam cycles with regard to superheating.

Regina, Sask. Regina's Power Supply, E. W. Bull. Elec. News, vol. 40, no. 12, June 15, 1931, p. 115, 1 fig. City is with population of approximately 60,000 and present maximum power demand is just over 15,000 kw.; steam generating plant has installed capacity of 31,000 kw. in six units; more modern plant consists of two 5000-kw. General Electric units and one 15,000 kw. C. A. Parsons unit, all operating at 3600 r.p.m.; C. A. Parsons unit was largest full expansion, single-cylinder steam turbine operating at this speed in existence, when commencing operation in May 1930.

Saskatoon, Sask. Saskatoon Steam Plant. Elec. News, vol. 40, no. 12, June 15, 1931, p. 105, 3 figs. 10,000 kw. high pressure unit installed; may become large base load station for Saskatchewan power commission.

STEAM ENGINES

Marine Lubrication. Lubricating Steam Reciprocating Engines, A. M. Tode. Mar. Eng. and Shipg. Age, vol. 6, nos. 5 and 6, May 1931, pp. 236–238, and June, pp. 288–290, 2 figs. Lubrication of bearings on marine reciprocating steam machinery; wick and hand-feed lubrication; viscosity of marine engine oil.

STEAM POWER PLANTS

Design. Die ver Haupttendenzen im heutigen Kraftwerkbau (Form Principal Tendencies in Modern Power Plant Design), F. Muenzinger. Elektrizitaetswirtschaft, vol. 30, no. 8, Apr. 1931, pp. 217–222, 11 figs. Author tried to show before Berlin section of V.D.I. that in modern design four tendencies are noted, i.e., perfection of process and equipment; improvements in material used and application of higher specific loads; shifting to larger boilers and engines; general measurements amounting to lowering of construction costs; savings obtainable in design for peak load steam power plants by deviation from standard practice are given here as addition to lecture.

Considerations in the Design of the Small Boiler Plant—IV, J. Breslove. Combustion, vol. 2, no. 11, May 1931, pp. 24–28 and 39, 7 figs. Design problems of following existing plants: Johnson Bronze Co., New Castle, Pa.; Hardie Bros. Co., Pittsburgh, Pa.; Follansbee Bros. Steel Co., Toronto, Ohio.

Dyehouses. Bleachery Steam and Power in Dependable Supply and at Low Cost, W. E. Biggs. South. Power Jl., vol. 49, no. 5, May 1931, pp. 34–39, 6 figs. Design, construction and operating features of power plant supplying steam and power to Crystal Springs Bleachery which consists of cotton mill rated at 25,000 spindles, bleachery rated at 1,500,000 yds. per week and printing plant; typical coal analysis; list of principal equipment.

High Pressure. 1400 Lb. in Texas. Power Plant Eng., vol. 35, no. 12, June 15, 1931, pp. 664–666, 5 figs. San Antonio Public Service Co. superimposes high pressure equipment on old 190 lb. plant; cross section of boiler, plant consists of 1450 lb., 810 deg. Foster Wheeler steam generating unit, with maximum capacity of 215,000 lb. per hr. supplying steam to Westinghouse 8000 kw. high-pressure turbine.

Erfahrungen mit Hoechstdruckanlagen (Experiences With Super-Pressure Steam Plants), Marguerre. Mitteilungen der Vereinigung der Grosskesselbesitzer E. V., no. 32, May 31, 1931, pp. 101–120, 33 figs. Experiences in power plant, Mannheim, Germany; difficulties encountered; boiler-tube corrosion; feedwater treatment; damages occurring in back of boiler were found to be due to stagnating water circulation in area

of too high gas temperatures; damages in superheater tubes; creep in steel; favorable experiences with Ruths accumulator; auxiliary equipment; observations of high-pressure plants in America.

Operation. Das Dampfkesselwesen auf der Weltkraftkonferenz Berlin 1930 (Steam Power Plants at World Power Conference, Berlin, 1930), C. Wolff. Sparwirtschaft, vol. 9, no. 4, Apr. 1931, pp. 147–152, 3 figs. Trend in development of steam power plants with particular regard to economic aspects and operating practice; draft and statistical data illustrate performance of representative types of equipment.

STEAM TABLES

International. Die neuen internationalen Rahmentafeln fuer Wasserdampf (New International Tables for Steam), E. J. M. Honigmann. Zeit. des Oesterreichischen Ingenieur und Architekten Vereines, vol. 83, May 1, 1931, pp. 152–153. Report of Subcommittees in connection with Sixth World Power Conference in Berlin; limits for saturated state, specific volume and heat content.

STEAM TURBINES

Efficiency. The Comparison of Steam Turbines. Engineer, vol. 151, no. 3934, June 5, 1931, pp. 629–630. Editorial discussion demonstrating difficulties that may arise in attempt to compare turbines on basis of their efficiency ratios.

Ljungstrom. Compound Turbines for Auxiliary Drive. Power Plant Eng., vol. 35, no. 12, June 15, 1931, pp. 646–647, 2 figs. Details of Sturtevant Ljunstrom compound turbines which drive forced and induced draft fans on new Hell Gate boiler units; control diagram of turbine unit.

Testing. Fascicule de la C.E.I. relatif aux turbines a vapeur—Part I and II (I.E.C. Publication on Steam Turbines). Int. Electrotech. Commission—Pub. 45, 1931, 15 pp., and Pub. 46, 49 pp., 22 figs. Publication is divided in two parts, namely: specification, and rules for acceptance tests. (In French and English.)

STEEL

Castings, Properties. Eigenschaften beruhigt und unberuhigt vergossenen Stahles (Properties of Killed and Open Cast Steel), W. Oertel and A. Schepers. Stahl und Eisen, vol. 51, no. 23, June 4, 1931, pp. 710–715, 16 figs. Determination of segregations in killed or tranquil and open or effervescent steel by chemical analyses as well as coarse-grain and fine-grain structural analysis; strength properties; behavior with cementation and annealing; recrystallization of killed and open steel, mechanical and magnetic aging; deep drawing capacity.

Embrittlement. Ueber Rotbruch des Stahls durch Metalle (Red Embrittlement of Steel by Metals), H. Schottky, K. Schichtel, and R. Stolle. Kruppsche Monatshafte, vol. 12, May 1931, pp. 100–105, 8 figs. Previously indexed from Archiv fuer das Eisenhuettenwesen, May 1931.

Hardening. Some Sources of Variation in Hardening Practice, H. J. French. Black and White, vol. 4, no. 1, July 1931 (Metal Edition), pp. 4–8, 5 figs. Factors affecting uniformity of results are variations in smoothness of surface, heat for hardening, effect of gases.

Manganese Sulphide Effect. The Physical Properties of Manganese Sulphide With Relation to Its Effects in Steel, E. C. Krekel. Colo. School Mines—Quarterly, vol. 25, no. 4, Oct. 1930, 30 pp., 12 figs. Conclusions of investigation are: melting point of manganese sulphide is very high, at least well above 1600 deg. cent.; manganese reacts with iron sulphide to form manganese sulphide and iron; manganese sulphide and iron form eutectic mixture.

Silicon Welding. Versuche zur Ermittlung der Schweissbarkeit des Siliziumstahls (Tests for Determination of Welding Properties of Silicon Steel), H. Grahl. Archiv. fuer das Eisenhuettenwesen, vol. 4, no. 12, June 1931, pp. 593–600, 12 figs. Review of literature and results of tests with gas and electric welding; influence of annealing process on strength of gas welds; reduction of oxidation with electric heating; welding temperatures; notch toughness of welds.

Surface Treatment. Influence of High-Frequency Electrical Oscillations on the Properties of Metals and Alloys, G. Mahoux and J. Grant. Metal Industry (Lond.), vol. 38, no. 24, June 12, 1931, p. 593. Mahoux has found that modifications may be produced by placing metal in electromagnetic oscillating circuit; electric treatment produces marked increases in hardness, degree of nitridation and resilience; reverse type of experiment, production of diffusion from center of testpiece outward produced encouraging results; advantages are stimulation of metallurgical processes, and production of reactions which cannot otherwise be carried out.

STOKERS

Automatic. Small Automatic Stokers Show Advantage Over Hand Firing, O. H. Henschel. South. Power Jl., vol. 49, no. 5, May 1931, pp. 54–55, 2 figs. Small unit stokers of both underfeed and overfeed types, designed and built for use with boilers of small capacity are now available in number of makes; as against hand-firing, units give better economy, enable use of cheaper coal, and have fuel feed and air supply under automatic, or semi-automatic control; economical aspects.

Economic Factors. The Stoker and Its Place in the Future of the Coal Industry, L. W. Smith, Jr. Min. Congress Jl., vol. 17, no. 6, June 1931, pp. 312 and 314. Analysis of five fundamental economic factors which favor utilization of coal over other types of fuel; until coal industry gets solidly behind automatic coal stokers, it cannot expect to compete with newer types of fuel.

Marine. Stokers and Water Walls on Steamship Beaverhill, H. S. Thoenebe. Mar. Eng. and Shipg. Age, vol. 36, no. 7, July 1931, pp. 339–340, 3 figs. Taylor stoker is of multiple-retort underfeed type, five retorts wide and 20 tuyeres long; operation is almost identical to that on land; apart from saving in coal, marine stoker is responsible for other advantages, such as: improved conditions in stokehold, steady steam supply, greater flexibility, high reserve capacity, and low maintenance.

SUPERHEATERS

Cracking. Ueberhitzerschaeden (Superheater Failures). Zeit. des Bayerischen Revisions-Vereins, vol. 35, no. 10, May 31, 1931, pp. 117–119 7 figs. Three cases of damages to superheaters are described, and means of prevention of superheater-tube failures suggested; cracks are generally due to high steam superheating accompanying high pressure.

Deposits on. Stroemungsphysikalische Vorgaenge in Ueberhitzern (Flow Phenomena in Superheaters), F. Michel. Waerme, vol. 54, no. 24, June 13, 1931, pp. 449–451, 5 figs. Tube heating surfaces in transverse current; deposits on superheaters; both inside and outside; steam flow in superheaters; heat transmission and draft loss.

Temperature Effect. High Steam Temperatures and Steel, Muenzinger. Metallurgist (Supp. to Engineer), June 26, 1931, pp. 86–87. High steam temperatures often cause peculiar swellings or blisters on superheater tubes; A.E.G. Research Institute investigated formation of oxide layer at higher temperatures; metallographic examination of structure of tubes from German superheater indicated that at damaged places, section had been weakened by corrosive action; it is concluded that heating surface of superheater was too large, and excessive steam and tube temperatures were attained. Translated from A.E.G. Metteilungen, Jan. 1930, (Kraftwerk).

T

TEXTILE MILLS

Waste Elimination. Growing Economic Significance of the Social Aspects of Mill Management, D. A. Wilcox. Silk, vol. 24, no. 6, June 1931, pp. 25–28. Causes of and responsibility for various kinds of economic waste such as waste of effort and money through lack of coordination between individual companies in same or related lines, duplication of effort in distribution, lack of uniformity of products, losses entailed by poor legislation forcing industry along uneconomic ways and similar losses.

THERMODYNAMICS

Absolute Zero. Warum ist der absolute Nullpunkt unerreichbar? (Why Is Absolute Zero Point Unattainable), H. Schmolke. Zeit. fuer die Gesamte Kaelte-Industrie, vol. 38, no. 6, June 9, 1931, pp. 86–88. Thermodynamic discussion with regard to heat theory of Nernst, which in its most general form can be termed principle of unattainable absolute zero point.

TUBES

Stresses. Fittings Control the Life of Metallic Tubing Subjected to Vibration, R. L. Templin. Automotive Industries, vol. 65, no. 2, July 11, 1931, pp. 50–51, 1 fig. Endurance characteristics of copper and aluminum tubing, according to tests made by Air Corps, Wright Field, and Aluminum Research Laboratories; under vibration conditions imposing stress of 13,000 lb. per sq. in. annealed copper tubing will withstand approximately $8^1/_2$ times as many cycles as aluminum alloy tubing.

TUNGSTEN CARBIDE

Cutting Tools. Milling With Tungsten Carbide Tools. Engineer, vol. 151, no. 3935, June 12, 1931, p. 659, 1 fig. Case of milling with inserted tooth cutter; subject is cast-iron pump body, one end of which has to be faced.

Cutting Materials—Yesterday and Tomorrow, A. G. Baumgartner. Am. Mach., vol. 74, no. 26, June 25, 1931, pp. 979–982, 7 figs. Opinions as to probable influence of tungsten carbide and future cutting mediums.

V

VIBRATIONS

Measurements. An Instrument for Measuring Small Displacements, B. F. Langer. Rev Sci. Instruments, vol. 2, no. 6, June 1931, pp 336–342, 3 figs. Instrument which measures and records small displacements such as vibrations and strains from dynamic loads; results of some recent development work on this instrument are given.

W

WAGE-PAYMENT PLANS

Western Electric Co. Wage Incentive Applications in the Western Electric Company. Nat. Assn. Cost Accountants—Bul., vol. 12, no. 21, July 1, 1931 (sec. 1), pp. 1759–1774. Wage payment practices of Western Electric Co.; ideals of management as they relate to wage incentive policies, and wage relationship between management and employees; outline of what is being done in developing these ideals into wage incentive practices.

WASTE ELIMINATION

Cost. The Cost Accountant and the Elimination of Waste, D. J. Hornberger. Nat. Assn. Cost Accountants—Bul., vol. 12, no. 20, June 15, 1931, pp. 1696–1703. Importance of waste to society as well as to individual, apparent tendencies, and few beliefs of modes of attack and future developments.

WAVE MECHANICS

Theories. Over Golfmechanica (Wave Mechanics), G. J. Van de Well. Ingenieur, vol. 46, no. 28, July 10, 1931, pp. 41–64, 2 figs. Emission and wave theory of light, quantum theory of Planck; photoelectric theory of Einstein; atom theory of Bohr; duality of light; wave theory of matter of De Broglie; duality of matter; wave mechanics of Schwedinger.

WELDING

Aluminum. See ALUMINUM, Welding and ALUMINUM ALLOYS, Welding.

Boilers. See BOILERS, Welding.

Steel. See STEEL, Silicon Welding.

Pipe Lines. See PIPE LINES, Welding.

Pressure Vessels. See PRESSURE VESSELS, Electric Welding.

Contract Work. Zur Frage des Akkordschweissens (Problem of Contract Work in Welding), H. Melhardt. Autogene Metallbearbeitung, vol. 24, no. 9, May 1, 1931, pp. 134–137; see also Autogenschweisser, vol. 4, no. 5, May 1931, pp. 74–77. Various aspects in favor and against contract work; respectively, wages, character of work, and human factor.

Preheating. Welding Facts and Figures, D. Richardson and E. W. Birch. Welding Jl., vol. 28, no. 332, May 1931, pp. 134–136. Use of coal-gas as preheating gas in cutting blowpipes; ethylene gas for welding and cutting purposes; methane as combustible gas for welding flame.

Testing. Untersuchungen ueber die Spannungsverteilung in kombinierten Stirn- und Flankennaehten (Stress Distribution in Combined Transverse and Longitudinal Seams), C. J. Hoppe. Elektroschweissung, vol. 2, no. 5, May 1931, pp. 89–92, 5 figs. Results of tests in materials testing laboratory in Brussels and comparison with theory; test taken is to explain behavior of such welds within elastic limits.

WROUGHT IRON

Progress. Wrought Iron, J. Aston. New England Water Works Assn.—Jl., vol. 45, no. 2, June 1931, pp. 188–196, 4 figs. Review of progress in manufacture of wrought iron; use of wrought-iron pipe in water works.